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MARKOV ANALYSIS OF THE BLAIRMORE GROUP (LOWER CRETACEOUS), ALBERTA FOOTHILLS

by

© BRUCE D. VINCENT

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

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THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled MARKOV ANALYSIS OF THE BLAIRMORE GROUP (LOWER CRETACEOUS), ALBERTA FOOTHILLS submitted by BRUCE DOUGLAS VINCENT in partial fulfilment of the requirements for the degree of Master of Science.

G.D. Williams
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Date 1977. April. 11

ABSTRACT

The Blairmore Group of the southern Alberta Foothills is a succession of continentally-deposited sedimentary rocks with which little has been done in terms of statistical cyclicity analysis and for which few inferences have been made about the depositional environments within the Blairmore alluvial plain.

Descriptions of samples from the three measured sections (using textural, petrographic, and sedimentological features) were subjected to cluster analysis and the resulting groups of samples (lithotypes) were dominated by the grain size of the samples. Cluster analysis proved to have little practical value in coding a sedimentary sequence for Markov chain analysis since essentially the same units could be identified using grain size alone.

The Blairmore Group in its type section and the Sheep River section contains a first-order Markov property. The Beaver Mines Formation of the group, when analyzed separately, also contains a first-order Markov property in these sections as well as in a section on Burnt Timber Creek. This is true when the sections were coded both as grain size lithologic units and as lithotypes.

Truncated fining-upward trends are to be expected in all of the sections with few non-random transitions between the finest and coarser lithologies.

The Blairmore Group as a whole contains no geological cyclicity, the definition of which is based on mathematical oscillating series. The Beaver Mines Formation in the Sheep River section is also

non-oscillatory. The very fine grained sandstones of the Beaver Mines in the type section and the siltstones in the Burnt Timber Creek section may be expected to occur at 4 metre intervals.

The streams active on the Blairmore floodplain were intermediate between meandering and braided. Their positions were stable for extended periods of time within narrow channel belts where multistory channel deposits were formed and which allowed thick overbank sequences to accumulate. Evidence of severe flooding is present in both the channel and overbank sediments. The climate was semi-arid to sub-humid with little vegetation on the floodplain.

The lack of fluvial cyclicity on the floodplain is obvious. The stable channel belts moving by avulsion and the disruptive influence of the Columbian tectonism to the west and southwest did not allow the natural development of fluvial cyclicity.

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CHAPTER 1

INTRODUCTION

1.1 Purpose and location of study

The Lower Cretaceous Blairmore Group of the Southern Alberta Foothills has long been recognized as a continentally-desposited succession of strata. The Blairmore is probably of fluvial origin and might be expected to show typical fluvial cycles. However, previous investigations of this topic are limited to a few qualitative observations. Other than the accepted generalization that the Blairmore Group was deposited on an alluvial plain, few attempts have been made to be more specific about the depositional environment.

The first purpose of this thesis was to test the Blairmore Group in selected areas for the presence of a first-order Markov chain property. From the Markov analysis, it was planned to determine the sequences of lithologies which should be expected in a measured section and to investigate the statistical cyclicity of the sections. Of equal importance was the objective of interpreting the depositional environment more specifically than simply as an alluvial plain.

The area chosen for the study lies in the southern Foothills of Alberta (Figure 1-1); three sections were measured and sampled in detail during the summer of 1975. The sections were the type section of the Blairmore Group along Mill and Gladstone Creeks (WSW of Pincher Creek), a section along the Sheep River (WSW of Calgary), and a section along Burnt Timber Creek (just south of the Red Deer River, NW of Calgary).

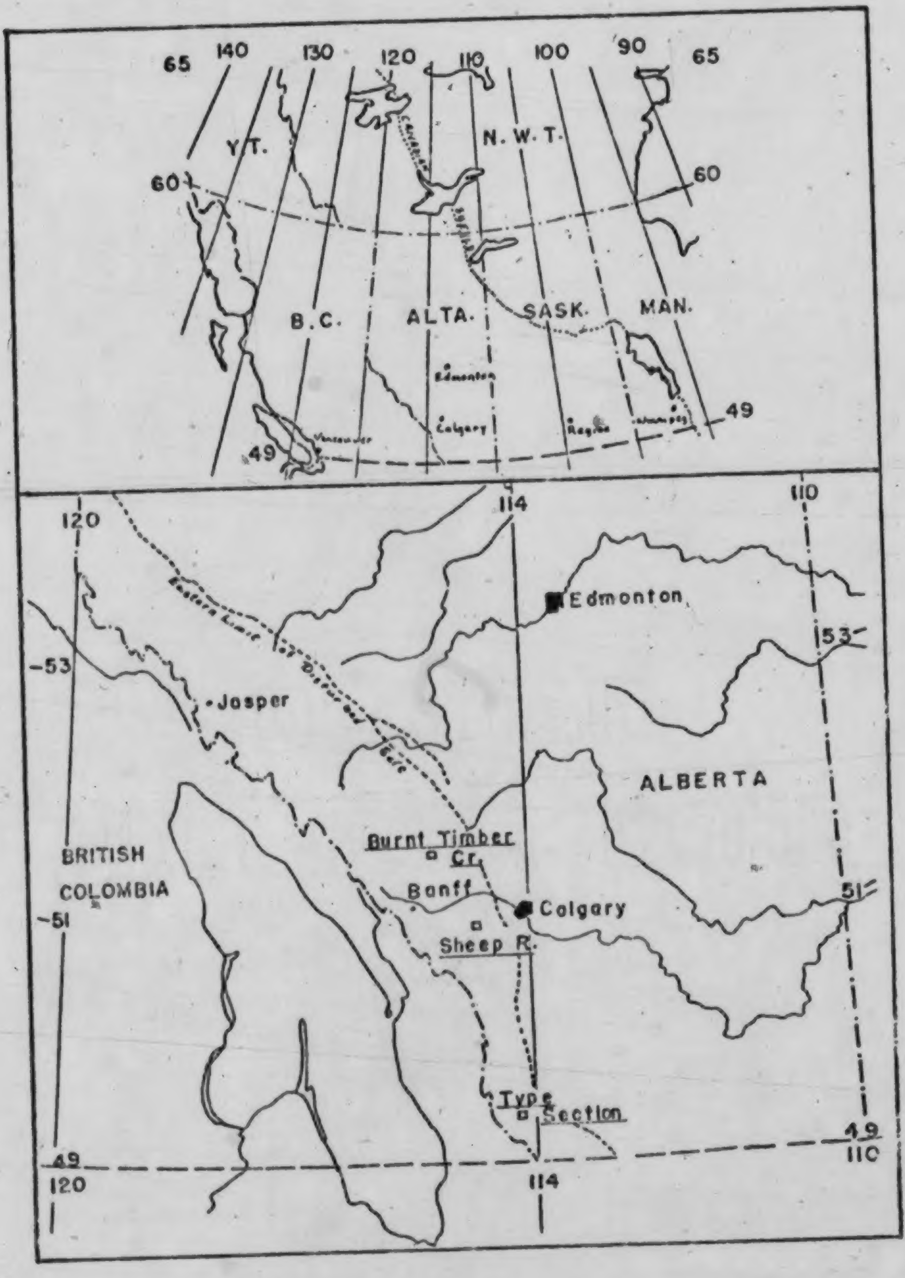

65
140
130
120
110
100
90
65
Y.T.
N.W.T.
60
60
B.C.
ALTA.
SASK.
MAN.
Edmonton
Calgary
Regina
Winnipeg
Vancouver
49
49
114
110
120
Eastern Limit of Disturbed Belt
Edmonton
53
-53
Jasper
ALBERTA
Burnt Timber Cr.
BRITISH COLOMBIA
Banff
Calgary
51
-51
Sheep R.
Type Section
49
110
49
120
114

Figure 1-1. Location map for the measured sections.

These were chosen on the criteria of the completeness of exposure, the thickness of the section, and the accessibility of the section. Their exact locations are given in Chapter 4.

1.2 Previous work

Study of the Blairmore Group began with the early work of G.M. Dawson (1886) and J.W. Dawson (1886). Leach (1912, 1914) was the first to use the term Blairmore Formation and Hage (1943) raised it to group status. This work was restricted to the southern Foothills of Alberta; McKay (1930) studied correlative strata to the north. Until the late 1950's no detailed studies were done and the Blairmore was dealt with only as a map unit on Geological Survey of Canada maps such as those by Hage (1946), Henderson (1946), Erdman (1947), and Norris (1955).

Rapson (1964) and Jansa (1972) concentrated their research on the transition between the underlying Kootenay Formation and the Blairmore Group. The Blairmore of the Foothills was more thoroughly studied by Glaister (1959), Mellon and Wall (1963), and Norris (1964). The Blairmore was divided into three formations by Mellon (1967) which are, in ascending order, the Gladstone, the Beaver Mines, and the Mill Creek Formations. Subsequent papers have included those by Holter and Mellon (1972) and McLean (1976, 1977).

Summaries of studies about equivalent strata under the plains are included in Brown (1976) and Leung (1976) in their reports on the Mannville Group of Southern Alberta and Saskatchewan respectively. Stelck (1975) has discussed basement control on Cretaceous sedimentation and Williams and Stelck (1975) have presented a picture of the paleogeography of western North America.

Cluster analysis, a technique of numerical taxonomy which was developed in the biological sciences, is a method of numerically comparing and classifying objects which became known to geologists largely through the work of Sokal and Sneath (1963). Imbrie and Purdy (1962), Klovan (1964), and Bonham-Carter (1965) were among the first to use cluster analysis in geological applications. Computer programs have been published by Bonham-Carter (1967) and McCammon and Wenniger (1970). Further investigations and uses have been reported by Sneath (1964), Parks (1966), McCammon (1968), Harbaugh and Merriam (1968), Demirmen (1972), Sneath and Sokal (1973), Ethier (1970, 1975), Hughes (1975), Wishart (1975), and Orford (1976).

What has become known as Markov chain analysis was developed by the Russian mathematician A.A. Markov in the early part of this century as a technique to establish the presence of "memory" effects in a succession of states or conditions. Some of the first applications of Markov analysis to geology were by Vistelius (1949), Vistelius and Faas (1965), Vistelius and Feigel'son (1965), Carr et al. (1966), and Krumbein (1967) who published the computer programs used in this study. Potter and Blakely (1968), Krumbein and Dacey (1969), Gingerich (1969), Dacey and Krumbein (1970), and Schwarzacher (1969, 1972, 1975) have been the main developers of the applications of Markov chains to geology. Some of the better published examples of these applications are those by Read (1969), Selley (1970), Doveton (1971), Lumsden (1973), Johnson and Cook (1973), Miall (1973, 1976), Ethier (1975), and Jones and Dixon (1976).

CHAPTER 2

METHODS OF STUDY

2.1 Section measurement and sample collection

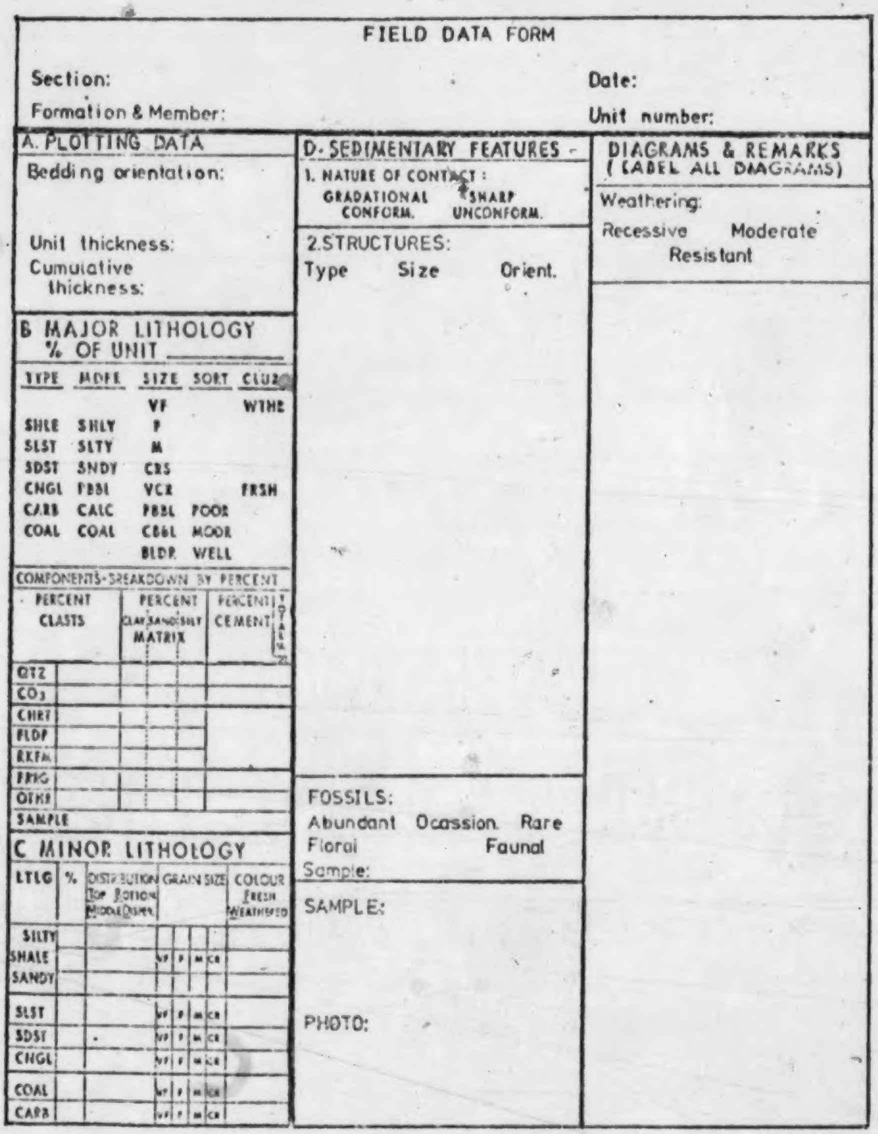
Three sections in the southern Foothills of Alberta were chosen for this study from Mellon's (1967) descriptions of the Blairmore outcrop localities, the choice being based on the completeness of the section available. Detailed measurement of these sections was conducted during the summer of 1975.

Each lithologic unit recognized in the field was described on a field data form (Figure 2-1). Grab samples of each lithologic unit were collected and where the unit was thicker than 2 metres, samples were taken at 2 metre intervals.

2.2 Sample classification

In order to code each measured section for Markov chain analysis (described in Section 2.3), two methods of classification were applied to the samples of each lithologic unit. The first method identified each unit according to the dominant grain size of the unit based on field descriptions and subsequent comparisons of the samples with grain size standards. The second method of classification used the numerical techniques of cluster analysis which is part of the larger system of classification methods known as numerical taxonomy.

Numerical taxonomy is the repeatable and objective grouping of objects according to the attributes of each object (Sneath and Sokal, 1973). For cluster analysis, the similarity or affinity between each



FIELD DATA FORM

Section: Date:

Formation & Member: Unit number:

A. PLOTTING DATA

Bedding orientation:

Unit thickness:

Cumulative thickness:

B MAJOR LITHOLOGY

% OF UNIT ______

TYPE	MDFR	SIZE	SORT	CLUR
		VF		WTHR
SHLE	SHLY	F		
SLST	SLTY	M		
SDST	SNDY	CRS		
CNGL	PBBL	VCR		FRSH
CARB	CALC	PBBL	POOR	
COAL	COAL	CBBL	MODR	
		BLDR	WELL	

COMPONENTS-BREAKDOWN BY PERCENT

	PERCENT CLASTS	PERCENT MATRIX CLAY	SAND	SILT	PERCENT CEMENT	TOTAL %
QTZ						
CO₃						
CHRT						
FLDP						
RKFM						
FRAG						
OTHR						
SAMPLE						

C MINOR LITHOLOGY

LTLG	%	DISTRIBUTION Top Bottom Middle Disper.	GRAIN SIZE				COLOUR Fresh Weathered
SILTY							
SHALE			VF	F	M	CR	
SANDY							
SLST			VF	F	M	CR	
SDST			VF	F	M	CR	
CNGL			VF	F	M	CR	
COAL			VF	F	M	CR	
CARB			VF	F	M	CR	

D. SEDIMENTARY FEATURES -

1. NATURE OF CONTACT:

GRADATIONAL CONFORM. SHARP UNCONFORM.

2. STRUCTURES:

Type Size Orient.

FOSSILS:

Abundant Ocassion. Rare

Floral Faunal

Sample:

SAMPLE:

PHOTO:

DIAGRAMS & REMARKS (LABEL ALL DIAGRAMS)

Weathering:

Recessive Moderate Resistant

Figure 2-1. An example of the type of field description form used for each lithologic unit recognized in the field.

pair of objects is calculated and the objects are then grouped or clustered according to the similarity coefficients. The result of the clustering is portrayed as a dendrograph. Cluster analysis was used in an attempt to define subtle similarities or differences between rock units not readily apparent otherwise.

Sample description

The 836 samples collected were slabbed and then examined with a binocular microscope. In addition, 27 thin sections of samples from the type section were prepared and studied for comparitive purposes. The description of each sample consisted of noting the following features which had been observed at the outcrop or during sample examination:

1. grain size (mean and range)
2. percentage of clasts
3. percentage of quartz
4. percentage of black chert
5. percentage of grey chert
6. percentage of rock fragments
7. percentage of clays
8. percentage of carbonaceous material
9. percentage of biotite
10. percentage of muscovite
11. percentage of pyrite
12. percentage of hematite
13. percentage of carbonate
14. fossils (abundance)
15. bioturbation (presence or absence)

16. roundness (mean and range)
17. sorting (poor, moderate, well)
18. laminations (size)
19. channelling (presence or absence)
20. ripple marks (type)
21. nature of the lower contact
22. concretions (presence or absence)
23. mud clasts (presence of absence)
24. colour (fresh and weathered)
25. cross-bedding (size and type)

The samples from the type section were described and coded according to the above attributes and were subjected to cluster analysis. The groupings of samples derived from this run were not used in the study for a number of reasons. Firstly, examination of the slabbed rocks with a binocular microscope did not permit easy or exact identification of the clast composition. The samples from the Beaver Mines Formation were particularly difficult to describe because of the similar appearance of many of the constituents. Detailed petrographic descriptions such as the one attempted can be done properly only with thin sections. Secondly, it was felt that the reliability of the estimations of mineral percentages was low, thus the use of these percentages as data could not be justified. This is somewhat supported by a study by Dennison and Shea (1966).

A second cluster analysis of the type section samples was done in which the petrographic data were deleted.by excluding attributes 2 to 13 inclusive. The samples clustered in much the same manner in both runs suggesting that clast composition did not have a large influence on the cluster analysis. The results of the second analysis were used for the type section in further study. The dendrographs of the two cluster analyses may be compared in Figures 4-4 and 4-5.

The Sheep River and the Burnt Timber Creek sections were coded slightly differently from the type section. Again the detailed petrographic data were excluded but a reflection of the composition of the samples was incorporated by estimating the percentage of dark minerals. Lerbekmo (1962) has suggested this type of description for a field classification of sandstones. Also an estimation of the volumetric proportion of carbonaceous material was included in the sample descriptions.

This modification of the attributes examined provided a quicker, more efficient, and more accurate description of the samples, yet produced results very similar to the more detailed descriptions. Also, for this type of study which is concerned with fluctuations within a depositional environment, variations in sandstone composition would probably be of minimal value.

Coding of data

In order to accommodate the various types of data used in the sample descriptions, a binary coding system was employed (Klovan, 1964; Bonham-Carter, 1965; Ethier, 1970; Sneath and Sokal, 1973; Hughes, 1975). The presence of an attribute was denoted by a 2 and the absence by a 1. If observation of the attribute was not possible, it was assigned a zero.

The types of data used and the method of coding for each type of data is explained below. Table 2-1 lists the attributes used in the sample descriptions and Figure 2-2 shows examples of sample descriptions and coding.

BINARY

- Bioturbation
- Channelling
- Concretions
- Mud clasts
- Types of cross-bedding
- Types of ripple marks

DISORDERED MULTISTATE

- Nature of lower contact
- Colour

ORDERED MULTISTATE

- Grain size *
- Roundness *
- Fossil
- Sorting
- Laminations
- Cross-bedding size

NUMERIC

- Percentage of clasts **
- Percentage of clasts of specific composition **
- Percentage of dark minerals
- Percentage of carbonaceous material

* Weighted, inclusion of mean and range.

** Used only in preliminary development of the coding system.

Table 2-1. Data type of the attributes used in the sample descriptions.

Sample description

Sample number	S167-1	S192-1
Unit thickness	1.7m.	0.35m.
Sample position	173.9m.	207.8m.
Grain size: mean	medium sand	very fine sand
range	fine to medium sand	silt to very fine sand
Roundness: mean	angular	subangular
range	v. angular to subangular	angular to subrounded
Sorting	moderate	poor
%dark minerals	20	20
%carbonaceous material	5	10
Nature of lower contact	sharp	sharp
Channelling?	no	no
Laminations: size	no	no
Ripples: assymetrical?	no	no
symmetrical?	no	no
climbing?	no	no
Cross bedding: size	large	no
type	trough	no
Mud clasts?	yes	no
Concretions?	no	no
Fossils: abundance?	none	present
Bioturbation?	no	no
Colour: fresh	dark green grey	dark green grey
weathered	grey	grey

Figure 2-2. An example of sample description, coding, and calculation of Jaccard's coefficient for two samples from the Sheep River section. Continued on the next page.

Coded data

SAMPLE NAME	UNIT THICK METRE	METRE ABOVE BASE	GRAIN SIZE 1 2 3 4 5 6 7 8	ROUNDNESS VA A SA SR R WR	SOR PMW	% DARK MINERAL	% CARB MATER	LWR CNT ESG	CHA	LAM	RIP ASC	X-BED SLPATATR	MUD	CON	FOSS ARPAB	BIO	COLOUR FRES LGDGGGDYRG	COLOUR WEAT GGGRGB
S167-1	1.70	173.9	1111111222111111	122221111111	121	12222221	1222211	121	1	111	111	21112	1	1	2111	1	1112	2111
S192-1	0.35	207.8	1112222111111111	111222211111	211	12222222	1222221	122	1	111	111	11111	1	1	1221	1	1112	2111

Explanation of coding

SAMPLE NAME
sample number

UNIT THICK METRE
unit thickness in metres

METRE ABOVE BASE
sample position in metres above the base of the section

GRAIN SIZE
1 clay
2 silt
3 very fine
4 fine
5 medium
6 coarse
7 very coarse
8 conglomerate

ROUNDNESS
VA very angular
A angular
SA subangular
SR subrounded
R rounded
WR well rounded

SOR
sorting
P poor
M moderate
W well

% DARK MINERAL
0, 0-1, 1-2, 2-4, 4-8, 8-16, 16-30, >30

% CARB MATER
% carbonaceous material
0, 0-1, 1-2, 2-4, 4-8, 8-16, > 16

LWR CNT
lower contact
E erosional
S sharp
G gradational

CHA
channelling

LAM
laminations
0-3 mm.
3-10 mm.
>10 mm.

RIP
ripple marks
A assymmetrical
S symmetrical
C climbing

X-BED
cross-bedding
S small
L large
P planar
TA tangential
TR trough

MUD
Mud clasts

CON
concretions

FOSS
fossils
A absent
R rare
P present
AB abundant

BIO
bioturbation

COLOUR
FRES fresh
LG light to dark grey
DG dark grey to black
GG green grey
DY dark green grey
RG red and green

WEAT weathered
G grey
GG green grey
RG red and green
B brown

Calculation of similarity coefficient

Number of positive matches = P = 15
Number of negative matches = N = 43
Number of mismatches = M = 19

Jaccard's coefficient = P / P + M
= 15 / 15 + 19
= 0.4411

Figure 2-2. Continued.

Binary data is data consisting of two contrasting conditions. One state was allocated for each attribute and the attribute's presence or absence was coded as a 2 or 1 respectively.

Disordered multistate data (nominal) is data consisting of three or more mutually exclusive categories (e.g., colour). Several states were established to include all possible categories. A 2 was entered in the appropriate state of each attribute and 1's were placed in the remaining states of that attribute.

Ordered multistate data (ordinal, semi-quantitative) is data measured on a qualitative hierarchy of contrasting states; data classified on an ordinal scale (e.g., grain size) with the ordinal scale divided into a number of classes or states. For example, the attribute of the presence of fossils was divided into the states of absent, rare, present, and abundant and an additive system of coding (Bonham-Carter, 1965; Sneath and Sokal, 1973) was used. If a sample was rare in its abundance of fossils a 2 was recorded in the rare state; if fossils were observed but neither rare nor abundant, 2's were entered in the rare and present states and 1's in the absent and abundant states.

Grain size and roundness were special cases where the mean and the range of the attribute were incorporated into the sample descriptions. To do this, each class of grain size and roundness were assigned two states as was done by Hughes (1975). In the two states of the class representing the attribute mean 2's were entered. In the classes which covered the range of the attribute a 2 was recorded in the state nearest the mean and a 1 in the other state. 1's were also entered in the rest of the states of that attribute. The weight of attributes coded in this way is thereby doubled.

Numeric data is data measured on a quantitative set of contrasting states; data measured on interval or ratio scales (e.g., proportion of dark minerals). The interval scales were subdivided into a number of percentage classes or states. The states were devised so that beginning with a class of 0 to 1 percent, each subsequent class included a range of percentages twice as large as the previous class. This method of division was used to give small, but possibly significant, variations at the low end of the percentage scale more weight; also estimations of small percentages of constituents are sometimes more accurate than larger proportions (Dennison and Shea, 1966; Hughes, 1975). The same additive system of coding as described for ordered multistate data was used for numeric data.

Similarity coefficients

The measurement of similarity between samples was done by calculation of similarity coefficients using a version of Bonham-Carter's (1967) CLUST3 computer program. Because of the inclusion of both qualitative and quantitative data and the use of the binary coding system, the type of similarity coefficient which was necessary was a coefficient of association. A coefficient of association is a correlation-type measure of similarity between samples in which the numerical value of the coefficient increases as the samples become more alike. Correlation-type measures of similarity must be distinguished from distance-type measures, the latter being a measure of the distance between samples which are located in some coordinate space based on similarity and in which the numerical value increases as the similarity decreases (samples are further apart) (McCammon, 1970). The distance-type coefficients will be used later in the plotting of the cluster analysis results.

The particular coefficient chosen for use was Jaccard's coefficient which has been widely used in previous geological studies (Bonham-Carter, 1965; Ethier, 1970; Hughes, 1975) and is defined by:

$J = P / P + M$ where J = Jaccard's coefficient,
P = number of positive matches,
and M = number of mismatches.

A positive match is obtained when 2's are present in the same category for the two objects being compared; two 1's are a negative match and a 1 and a 2 are a mismatch. In any comparison where a state was zero that state was excluded from the comparison. Negative matches are not included in Jaccard's coefficient as they may cause a high similarity between objects having a large number of mutually absent states which is not desirable (Sneath and Sokal, 1973).

The pair-wise similarity coefficients so calculated range from 1.0 to 0.0, the end points being complete similarity and complete dissimilarity respectively. These measures of similarity were stored in the lower half of an n x n symmetrical matrix (n being the number of samples) for input to cluster analysis.

Cluster analysis

Cluster analysis is the grouping of objects according to their mutual similarity by means of similarity coefficients. The result is a graphic hierarchical display of the similarity among all of the objects used in the analysis. The first type of graphic display used was a dendrogram (or phenogram of Sokal and Sneath, 1963). On a dendrogram, the samples were equally-spaced along one axis while the other axis was scaled into levels of similarity using a correlation-type measure of similarity. The samples were joined by vertical and horizontal lines with the lines parallel to the sample axis representing the level of similarity between samples (Bonham-Carter, 1967). McCammon (1968) developed a second type of display which he called a dendrograph. On a dendrograph, one axis was again scaled in correlation-type measures of similarity which showed the level of similarity within a group of objects. Along the second axis, samples were not equally-spaced but separated according to a distance-type measure of similarity and which showed the distance, or dissimilarity, between groups of objects. The objects were joined in the same manner as in a dendrogram.

McCammon and Wenniger (1970) published a computer program DENDRO which was used to group the objects and to generate dendrographs for each set of samples of this study. In order to use this program, the correlation-type measures of similarity, the Jaccard's coefficients, were first converted to a distance-type measure by an arc cosine transformation (McCammon and Wenniger, 1970, p. 2).

The two groups of objects having the lowest pair-wise distance (or highest similarity) were joined at each iterative stage of clustering by the unweighted pair-group method (McCammon and Wenniger, 1970). The algorithm used was documented by Lance and Williams (1967). In order to calculate what the within-group distance would be if groups h and k were joined (where group k consists of previously joined groups i and j), the following formula would be used:

$$d_{hk} = \frac{n_i}{n_k} \cdot \frac{1}{n_h n_i} \cdot \sum_{h,j} s_{hi} + \frac{n_i}{n_k} \cdot \frac{1}{n_k n_j} \cdot \sum_{h,j} s_{hj}$$

where: d_{hk} = average within-group pair-wise distance between groups h and k,

n_i = number of objects in group i,

s_{hi} = pair-wise distance between h and i

(Lance and Williams, 1967, p. 375).

The between-group distances were calculated in the same way. The within-group and between-group distances could be converted to correlation-type measures of similarity by taking their cosines.

After the objects had been clustered according to the above algorithm, the program plotted a dendrograph portraying the relationships among all of the samples. The partitioning of a dendrograph into useful clusters is complicated by the fact that there are no statistical tests available to evaluate the randomness of the objects or the validity of the resultant clusters. Most of the preliminary work on cluster analysis provided only arbitrary methods for the division of dendrograms. Parks (1966, p. 713) suggested that the observer could pick out groups ". . . at any desired level of similarity." Bonham-Carter (1965, p. 492) tested his clusters by seeing if they made ". . . geological sense." McCammon (1968, p. 1666) was more objective when he matched ". . . the wider gaps between hierarchical levels with the wider gaps between clusters." Demirmen (1972) formalized such suggestions into the following criteria:

Criterion A. The chosen groups should stand out from the neighbouring clusters (same as McCammon's suggestion).

Criterion B. It should be possible to produce a number of groups each containing a small number of objects with no one group containing a large proportion of the sample set.

Criterion C. The number of groups should be practical value.

Criterion D. If more than one clustering procedure is to be used the same groups should be apparent in each resultant dendrograph.

The suggestions of McCammon and Demirmen were used in the separation of clusters in this study. Demirmen's Criterion C was important in that the number of clusters had to be kept small in order to obtain sufficient transition counts between units for Markov analysis. All of the separated clusters, except one, grouped above the 0.5 level of similarity, whereas a random set of samples would have clustered at or near the 0.0 level (McCammon, 1968).

Each separated cluster of samples was given an "average" description and designated as a specific "lithotype." The measured sections were then coded according to these lithotypes for Markov analyses. Descriptions of the lithotypes are included in Chapter 4 under the discussion of the appropriate measured section. The dendrographs are presented in Figures 4-4, 4-5, 4-6, 4-9, 4-10 and 4-13.

2.3 Markov chain analysis

With the development of mathematical geology, attempts have been made to describe geological processes in terms of mathematical models. The two extremes of such models are random, or independent event, processes and deterministic processes. An intermediate class of statistical models are known as stochastic processes and have partial ordering but also a degree of randomness (Krumbein, 1967).

The Markov chain process is a stochastic process of particular applicability to geological studies. The first use of Markov models was by the Russian mathematician A.A. Markov who studied the alternation of vowels and consonants in Pushkin's poem "Onegin" (Doveton, 1971). The theory of Markov chain has been further developed by later mathematicians, for example, Kemeny and Snell (1960).

In a sequence of events, the probability of the occurrence of an event X_t at time t is dependent only upon the immediately preceding event X_{t-1} at time t-1. This dependency upon the previous event is the Markov chain property or Markovian "memory" of the sequence of events and can be expressed formally by:

$$P \left\{ X_n = x \;\middle|\; X_{n-1} = y \right\} \quad , (n = 1, 2, 3, . . .)$$

(Kemeny and Snell, 1960). This definition is for a single-dependency first-order Markov chain. In these chains, the dependency involves only one preceding state (single-dependency) and that state is the immediately preceding one (first-order). Higher-order Markov chains are possible where the dependency extends back 2, 3, or more steps and these may be single- or multi-dependent (Harbaugh and Bonham-Carter, 1970).

In a stratigraphic section the occurrence of an event is the presence of a specific lithology with its presence dependent only upon the immediately preceding lithologic type. The dependency of lithologic successions can be expressed as probabilities which are tabulated in the transition probability matrix with the form:

$$\begin{array}{c|ccc} & S1 & S2 & S3 \\ \hline S1 & p_{11} & p_{12} & p_{13} \\ S2 & p_{21} & p_{22} & p_{23} \\ S3 & p_{31} & p_{32} & p_{33} \end{array}$$

If S1 represents sandstone, S2 claystone, and S3 limestone then p_{12} is the probability of sandstone being followed by claystone and p_{13} the probability of sandstone followed by limestone (Potter and Blakely, 1968). The construction of this and other matrices is discussed below.

Much of the work with Markov chain models in sedimentology has been in the simulation of stratigraphic sections (Krumbein, 1967; Potter and Blakely, 1968; Read, 1969; Krumbein and Dacey, 1969; Lumsden, 1975). From these experiments arose a number of methods of sampling a sedimentary sequence for Markov chain analysis with emphasis on the type of statistical distribution of the lithologic unit thicknesses. Each sampling method necessitated the development of a slightly different Markov chain model, each with its own specific definition, structure of the transition probability matrix, and geological implications.

Embedded Markov chain

The transitions counted for an embedded Markov chain analysis are only those between lithologic units. In this case, it is obvious that adjacent lithologies cannot be identical and the elements of the principal diagonal of the transition probability matrix will be zero ($p_{ij} = 0$, where $i = j$) (Krumbein and Dacey, 1969). There is no way to incorporate information about lithologic thicknesses in an embedded Markov chain and the specific type of distribution of lithologic thicknesses is not included in the definition (Krumbein and Dacey, 1969).

This type of Markov chain emphasizes the change between succeeding lithologic units and focuses on the evolution of the depositional environment (Miall, 1973).

Regular Markov chain

For a regular Markov chain, the transitions are recorded by noting the type of lithology present at adjacent steps over a series of equally-spaced intervals (Krumbein and Dacey, 1969). In this case, a lithology may be followed by the same lithology and therefore, the elements of the principal diagonal of the transition probability matrix will not necessarily equal zero. By definition (Krumbein and Dacey, 1969), the lithologic unit thicknesses of a sequence represented by a regular Markov chain must be geometrically distributed for discrete data or exponentially distributed for continuous data. If these distributions are not present, an embedded Markov or a semi-Markov model must be employed (Krumbein and Dacey, 1969; Dacey and Krumbein, 1970).

A regular Markov chain allows a more accurate measure of relative frequencies of the component lithologies at the expense of the accuracy available in step-by-step depositional changes (Dacey and Krumbein, 1969; Miall, 1973). The difficulty in choosing a representative sample interval has been recognized by several authors, notably Krumbein (1967), Read (1969), and Miall (1973). If too large an interval is chosen, the analysis will miss any potentially important thin units. With an interval too small, excessively large figures will appear in the principal diagonal which will overshadow Markovian tendencies as well as yield extremely high values in the Chi-square test (discussed below).

Also, the optimum sample interval may differ among co-existing lithologies.

Multistory facies analysis

Carr *et al*. (1966) initiated the concept of multistory lithologies which are gross lithologic units that may be subdivided by sedimentological variations. A section studied with the inclusion of multistory lithologies would use a variation of an embedded Markov model, however the elements of the principal diagonal of the transition matrix would not equal zero but would be expected to remain small (Dacey and Krumbein, 1970). Lumsden (1971) coined the term "multistory facies analysis" for this type of Markov chain analysis.

Read (1966) noted that no author had attempted to define the criteria by which adjacent lithologies can be identified as subdivisions of a lithologic unit, but which are not distinct enough to define separate lithologies. No such criteria have been found in more recent literature by this author.

Semi-Markov models

The semi-Markov model has been developed by Krumbein and Dacey (1969), Dacey and Krumbein (1970) and Schwarzacher (1972, 1975) for sequences which have a first-order Markov property but for which the lithologic unit thicknesses are defined by an independent discrete random variable governed by a mechanism and time scale distinct from the controls on the type of lithology deposited. The lithologic unit thicknesses are considered as the time the system waits in a lithology before passing onto the succeeding lithology. Schwarzacher (1972) suggested the waiting time or thicknesses may be described by a Gamma distribution. The three authors referred to above have developed the geological applications of semi-Markov models through theoretical discussions but no practical analysis has yet been attempted in geology.

Stationarity

A prerequisite condition for the Markov analysis of a stratigraphic section is stationarity of the section (Doveton, 1971). This is defined as the condition that the depositional process remained the same during the formation of the whole section under consideration (Potter and Blakely, 1968), i.e., the same depositional process controlled sedimentation for all of the section being considered.

Testing for stationarity is not highly refined. Doveton (1971) suggested visually comparing the proportions of lithologies present in various intervals of the complete section. The proportions should remain the same and this way be observed at the outcrop or in a graphic log of the section. The section may be subdivided into intervals and transition probabilities from those intervals may be compared for similarity and therefore, stationarity (Miall, 1973). Vistelius and Faas (1965) termed a section to be homogeneous or stationary if transition matrices of subsections produced similar Chi-square values but they did not describe the test used.

Transition matrices and significance test

The first procedure in a Markov chain analysis of a sedimentary succession which consists of s states or lithologies is to obtain a count of the upward transitions between various states. This count is consolidated into the s x s *tally* or *transition frequency matrix*, N (Krumbein, 1967) with the elements n_{ij}. The row sums, $\sum_{1}^{s} n_{ij} = n_i$, or the column sums, $\sum_{i}^{s} n_{ij} = n_j$, may be calculated to yield the total number of transitions, n, in the sequence. An example of this and other matrices are presented in Figure 2-3.

The probability of the transition from a state to another state is calculated by the general formula:

$$P_{ij} = n_{ij} / n_i$$

These probabilities are summarized in the transition probability matrix, P, in which each row sums to 1.0. This matrix is the most expressive in a Markov analysis and is used for further interpretation.

In order to test for the presence of the Markov property in a sequence, Anderson and Goodman (1957) devised the statistic

$$-2\log_e \lambda = 2 \sum_{ij}^{s} n_{ij} \log_e (P_{ij} / P_j)$$

where the quantity $(-2\log_e \lambda)$ for s states is asymptotically distributed, a Chi-square distribution with $(s-1)^2$ degrees of freedom for a regular Markov chain or $(s-1)^2-s$ degrees of freedom for an embedded Markov chain. The null hypothesis for this test is that the sequence under consideration was produced by a random or independent events process.

The probability of a transition occurring randomly is

$$e_{ij} = n_j / (n-n_i)$$

for an embedded Markov chain and by

$$e_{ij} = n_j / n$$

for a regular Markov chain (Potter and Blakely, 1968; Read, 1969). These probabilities, indicative of a random process, are combined into the independent events matrix, E.

Transition frequency matrix = N

	I	II	III	IV	n_i
I	0	37	3	2	42
II	21	0	41	14	76
III	20	25	0	0	45
IV	1	14	1	0	16
n_j	42	76	45	16	179 = n

Independent events matrix = E

	I	II	III	IV
I	.00	.55	.33	.12
II	.41	.00	.43	.16
III	.31	.57	.00	.12
IV	.26	.47	.27	.00

Transition probability matrix = P

	I	II	III	IV
I	.00	.88	.07	.05
II	.28	.00	.54	.18
III	.44	.56	.00	.00
IV	.06	.88	.06	.00

Difference matrix = D

	I	II	III	IV
I	.00	.33	-.26	-.07
II	-.13	.00	.11	.02
III	.13	-.01	.00	-.12
IV	-.20	.41	-.21	.00

where I is sandstone, II is mudstone, III is lignite, and IV is limestone.

Figure 2-3. Examples of types of transition matrices (after Gingerich, 1969).

Greater insight may be gained into the most prominent non-random transitions by constructing the difference matrix, D, using the formula

$$d_{ij} = p_{ij} - e_{ij}$$

which is the subtraction of an element of the independent events matrix from the equivalent element of the transition probability matrix (Gingerich, 1969). Positive elements in the difference matrix represent those transitions which occur with greater than random frequency.

2.4 Cyclicity and Markov chain analysis

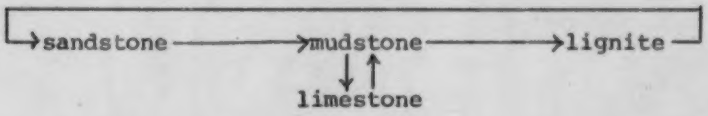
Man has a basic drive to explain his surroundings and to find order in complex, random-appearing systems (Zeller, 1964). Geologists exemplify this phenomenon, and cyclicity of sedimentary sequences is a particular case in which geologists attempt to find order in a system and then try to explain the cause (Schwarzacher, 1975).

The development of the concept of cyclicity in geology began in the early 1800's, and soon afterward, the study of cyclicity of particular sedimentary sequences began with the early work done on the Carboniferous coal measures of eastern North America and Britain.

By 1962, Duff and Walton found a great proliferation of confusing and ill-defined terms in the literature which they attempted to overcome by adding their own definitions. A cycle in sedimentary rocks was defined to be ". . . a group of rocks which tend to occur in a certain order and which contains one unit which is repeated frequently throughout the succession" (Duff and Walton, 1962, p. 247). In the same paper, a modal cycle was defined as the group of rocks most common in a succession. Criticisms of the concept of a modal cycle are that it represents only a portion of the total sequence and that the tops and bottoms of the cycle have to be chosen arbitrarily. (Schwarzacher, 1969). Controversy still arises over definitions of geological cyclicity but it is generally accepted that a sequence is cyclic or rhythmic if the rock types are ordered into patterns such as ABCABC . . . or ABCBABCBA . . . or CBACBA . . ., etc. (Duff, *et al*., 1967; Schwarzacher, 1969).

It should be obvious that a cyclic sedimentary sequence will have a Markovian memory or dependency since the same series occur repeatedly in the succession. A critical point is that a sequence with Markovian dependency may not be cyclic according to the above definition (Ethier, 1975).

In the sequence he studied, Gingerich (1969) took the positive elements of the difference matrix (the example used in Figure 2-3) as the most probable upward transitions between rock types and graphically displayed the relationships as follows:



To this representation he applied the term "fully developed cycle." Other authors, using the same method and similar diagrams, have applied terms such as "Markovian transition scheme" (Doveton, 1971), "cyclic processes" or "facies relationships" (Miall, 1973), and "Markovian cycle" (Jones and Dixon, 1976). Some of the terms imply cyclicity which may not be present in the sequences represented and so, the best term to use would seem to be Ethier's (1975) "transition pattern."

Schwarzacher (1969) has applied mathematical concepts to geological cyclicity and defined cyclicity to be the repetition of one or more lithologies in a vertical succession at a preferred period of recurrence. In mathematical terms, the repetition of an event regularly in time would represent perfect periodicity. If the repetitions were damped for some natural reason, the series of events would have a quasi-periodicity or oscillating behavior (Schwarzacher, 1969).

Powering the transition probability matrix

Upon raising the transition probability matrix to successive powers (P^1, P^2, P^3, . . .) the matrix will converge to a matrix P^n, $n \rightarrow \infty$, in which all the rows are identical. Any row of this matrix is called the stable probability vector which represents the proportions of the various lithologies in a sequence if the matrix had originally been structured as a regular Markov chain (Potter and Blakely, 1968).

The elements of the transition matrix may approach the stable value exponentially or by a series of damped oscillations. Graphically this convergence is represented by plotting the transition probability of an element of the matrix at successive powers against the particular power (Figure 2-4B). Those elements which approach the stable value by exponential curves are termed non-oscillating and have no period of recurrence within the section. Oscillating curves are generated by the transitions with a specific period of recurrence (Schwarzacher, 1968).

The period of recurrence may be determined by calculating and plotting the recurrence probability, f_j, by the formula

$$f_j^n = p_{jj}^n - f_j^1\, p_{jj}^{n-1} - \ldots .\; f_j^{n-1}\, p_{jj}^1$$

(Schwarzacher, 1969) (Figure 2-4C). The period of recurrence of a lithology is the power opposite the highest value on the recurrence

A.

$$\begin{bmatrix} 0.5 & 0.3 & 0.2 \\ 0.5 & 0.3 & 0.2 \\ 0.5 & 0.3 & 0.2 \end{bmatrix} \quad \begin{bmatrix} 0.8 & 0.1 & 0.1 \\ 0.2 & 0.1 & 0.7 \\ 0.4 & 0.5 & 0.1 \end{bmatrix} \quad \begin{bmatrix} 0.1 & 0.8 & 0.1 \\ 0.1 & 0.2 & 0.7 \\ 0.9 & 0.0 & 0.1 \end{bmatrix} \quad \begin{bmatrix} 0.0 & 1.0 & 0.0 \\ 0.0 & 0.0 & 1.0 \\ 1.0 & 0.0 & 0.0 \end{bmatrix}$$

(a) (b) (c) (d)

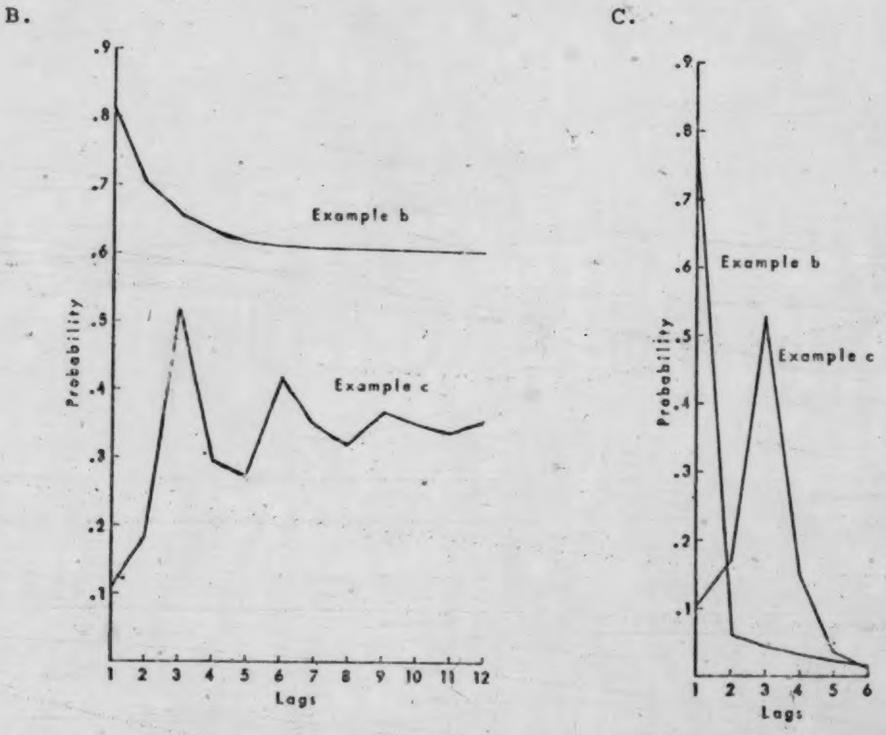


Figure 2-4. Examples of plots of powered transition probabilities (B.) and recurrence probabilities (C.) of the first elements of matrices b and c shown in (A.) (after Schwarzacher, 1969, p.20 and 21).

probability curve. The power represents the number of steps away from the original occurrence where a lithology may be expected again. This may be converted into distance by multiplying the number of steps by the sample interval used in generating the original matrix (Schwarzacher 1969).

Eigenvalues of the transition probability matrix

Vistelius and Faas (1965) and Schwarzacher (1969) suggested the eigenvalues of a transition probability matrix may be used to yield more information about the oscillating nature of the matrix. Some characteristics of matrices must be mentioned for a lucid discussion.

A diagonal matrix D of the form

$$D = \begin{bmatrix} \lambda_1 \ldots 0 \ldots 0 \\ \cdots\cdots\cdots\cdots\cdots \\ 0 \ldots \lambda_i \ldots 0 \\ \cdots\cdots\cdots\cdots\cdots \\ 0 \ldots 0 \ldots \lambda_n \end{bmatrix}$$

becomes the following matrix after successive multiplication with itself (Jacquard, 1974, p.543).

$$D^g = \begin{bmatrix} \lambda_1^g \ldots 0 \ldots 0 \\ \cdots\cdots\cdots\cdots\cdots \\ 0 \ldots \lambda_i^g \ldots 0 \\ \cdots\cdots\cdots\cdots\cdots \\ 0 \ldots 0 \ldots \lambda_n^g \end{bmatrix}$$

The powered value of an n x n square matrix A may be found if A can be expressed as the product of three matrices

$$A = CDC^{-1}$$

where D is a diagonal matrix and C^{-1} is the inverse of C (Jacquard, 1974, p.543).

By multiplying both sides of the above equation, the matrix AC becomes equivalent to a set of n homogeneous equations with the form

$$a_{n1}c_{1i} + \ldots + a_{nk}c_{ki} + \ldots + (a_{nn} - \lambda_i)c_{ni} = 0$$

If the determinant of the coefficients of these equations is expanded to a polynominal equation, the roots, λ_1 to λ_n, may be found and are the eigenvalues of the matrix A. The constants, c, may be found and form the matrix C which is the column eigenvector (Jacquard, 1974).

Therefore, it can be seen that the eigenvalues of a matrix will control the convergence of the matrix A (Jacquard, 1974, p. 551) since

$$A^g = CD^gC^{-1} .$$

A stochastic matrix such as a transition probability matrix will have at least one eigenvalue equal to one and the rest will be equal to or smaller than unity. If there are negative or complex eigenvalues in the matrix then the higher-order transition probabilities will approach the stable matrix by a series of damped oscillations (Jacquard, 1974; Schwarzacher, 1975).

The amount of damping of the oscillating may be measured by finding the modulus of the complex eigenvalues (Schwarzacher, 1975). In a periodic case, the modulus of the complex eigenvalue $|\lambda| = 1$; a modulus near one represents quasiperiodicity (Vistelius and Faas, 1965);

as the modulus approaches zero, the damping increases.

Geological cyclicity

The term cyclicity has two distinct meanings in this paper and they are distinguished by the terms fluvial cyclicity and geological cyclicity. Geological cyclicity was defined by Schwarzacher (1969) and is discussed in this section. It is a thickness-based cyclicity since it is dependent on the thickness-based regular Markov chain structure. Fluvial cyclicity is the widely-used conception of cyclicity as it applies to alluvial plain sediments. This type of cyclicity is better defined as a process-based cyclicity as it is derived from observations of sedimentological features and the embedded Markov chain.

Schwarzacher (1969) defined "geological cyclicity" to be ". . . the property of a series in which the higher transition probabilities approach equilibrium by a series of more or less damped oscillations" (p. 22). There are two limits to this definition with the first being perfect periodicity and the second, damping so extreme as to cause a recurrence maximum at step or power one which is not considered a geological cycle. Table 2-2 summarizes the definitions of the possible types of stratigraphic series.

The matrices in Figure 2-4A represent the types of series listed in Table 2-2. Matrix (a) is an independent random series and matrix (d) is a deterministic periodic series. The transition probabilities of the first element for matrix (b) represent a non-oscillating random series. The transition probabilities and recurrence probabilities of the first element of matrix (c) shows an oscillating random series with a period of recurrence of three units.

Type of series	Transition matrix
Independent random process	Rows of transition probabilities are identical and remain the same upon powering.
Non-oscillating random series	Transition and recurrence probabilities exponentially approach a constant value.
Oscillating random series (geological cycles)	Transition probabilities reach stable value in a series of damped oscillations. Recurrence probability maxima different from one.
Deterministic process (mathematical cycles)	Powers of transition probabilities do not converge. Spike like recurrence probability maxima.

Table 2-2. Types of stratigraphic series (modified after Schwarzacher, 1975, p. 260)

Since no quantitative analysis has yet defined an independent random nor a deterministic sequence of sedimentary rocks (Schwarzacher, 1975), stratigraphic sections must be tested for oscillatory behavior in order to differentiate between oscillating and non-oscillating series.

CHAPTER 3

REGIONAL STRATIGRAPHY OF THE BLAIRMORE GROUP

3.1 Stratigraphy

The first geological report about the Lower Cretaceous continental strata of southern Alberta was published by G.M. Dawson (1886) who divided the sequence into a lower coal-bearing sequence and an upper "barren" sequence, overlain in the Crowsnest Pass region by tuffs and agglomerates. On the basis of two distinct floras, he applied the name "Kootanie series" to the coal-bearing strata and to the lower, unfossiliferous, "barren" beds and the name "Dakota series" to the higher, fossiliferous strata just below the pyroclastics.

J.W. Dawson (1886) proposed a threefold division to this succession based on a study of G.W. Dawson's fossil collection: a lower "Kootanie series," an "Intermediate series," and an upper "Mill Creek series."

Leach (1912) restricted J.W. Dawson's "Kootanie series" to the coal-bearing strata and renamed it the "Kootenay Formation." In 1914, Leach applied the name "Blairmore Formation" to the sequence of continental clastics between a conglomerate at the top of the Kootenay Formation and the overlying "Crowsnest volcanics" (replacing "Dakota Formation"). The conglomerate was moved from the Kootenay Formation to the base of the Blairmore Formation by Rose (1917), who recognized the unconformity at the base of the conglomerate.

Hage (1943) was the first to use the terms Blairmore Group and

Crowsnest Formation, the latter being the pyroclastic sequence at the top of the group. Norris (1964, p. 515) divided Hage's Blairmore Group into the basal Cadomin Formation overlain by the informal units: "lower Blairmore, 'Calcareous Member,' middle Blairmore, and upper Blairmore" on the basis of sandstone petrography and the presence or absence of limestone and conglomerate.

At the same time, Mellon and Wall (1963), using petrographic data as well as floral and microfossil distributions, divided the Blairmore into the Lower Blairmore (which included the Calcareous Member), the Middle Blairmore, and the Upper Blairmore. For the first time, the Crowsnest volcanics were included in the Blairmore Group instead of being described as an overlying formation.

Mellon (1967) applied formal names to the previous informal divisions of the Blairmore Group and also proposed a type section for the group along Gladstone and Mill Creeks in the southwestern Foothills of Alberta. Mellon and Wall's (1963) Lower, Middle, and Upper Blairmore became respectively the Gladstone Formation with the Calcareous Member at the top, the Beaver Mines Formation, and the Mill Creek Formation with the pyroclastics at the top denoted as the Crowsnest Member. These names are restricted to the south and south-central Foothills of Alberta.

Gladstone Formation

The oldest formation of the Blairmore Group is the Gladstone Formation, the base of which is marked by a conspicuous chert-quartzite conglomerate or pebbly sandstone which is equivalent to the Cadomin conglomerate. The conglomerate is regionally unconformable on the underlying Kootenay Formation. The local erosional relief at the base of the conglomerate is normally less than one metre, however in the Crowsnest Pass region, the relief is several metres over a few kilometres with the amount of erosion increasing toward the east (Norris, 1964; Vincent, 1976).

The middle portion of the Gladstone consists of interbedded claystones, siltstones, and sandstones. The sandy units are distinctive in the abundance of rounded quartz and chert, locally abundant transported dolomite, the scarcity of metamorphic and igneous detritus, and heavy minerals of zircon, tourmaline, and rutile (Mellon, 1967).

The Gladstone Formation is capped by the Calcareous Member in southern Alberta. This member consists of interbedded fresh-water limestones and calcareous shales and extends northward to the vicinity of the Red Deer River and eastward under the southern Alberta Plains (Mellon, 1967).

Beaver Mines Formation

The contact between the Gladstone Formation and the overlying Beaver Mines Formation is sharp and well-defined, being based mainly on petrographic differences. The Beaver Mines Formation is a sequence of green-grey, feldspathic sandstones, local conglomerates, and siltstones interbedded with grey and mottled red and green silty claystones (Mellon, 1967). No regional markers are present in the Beaver Mines Formation comparable to the basal conglomerate and the Calcareous Member of the Gladstone (Mellon and Wall, 1963).

The sandstones of the Beaver Mines Formation are very heterogeneous in composition, consisting of angular quartz, feldspar, and finely crystalline metasedimentary and volcanic rock fragments. The distinguishing features are the high proportion of volcanic detritus, abundance of plagioclase and chlorite, heavy minerals dominated by epidote and biotite, and the wide variety of authigenic cements (Mellon, 1967).

The differences in sandstone petrography among the three formations are clearly seen in the ternary diagram in Figure 3-1.

The Gladstone and Beaver Mines Formations both contain a non-dicotyledonous flora which Bell (1956) and Mellon (1967) termed "lower Blairmore flora."

Mill Creek Formation

A regional break in sedimentation between the Beaver Mines Formation and the succeeding Mill Creek Formation is recognized by changes in sandstone composition and floral content between the two formations.

The Mill Creek Formation is restricted to southern Alberta south of the Bow River. The formation consists of quartzose, cherty sandstone and conglomerate and varicoloured claystones which grade upward into the alkali-rich pyroclastic rocks of the Crowsnest Member.

The sandstones of the lower sedimentary part of the formation are composed primarily of quartzose detritus and fine grained sedimentary or metasedimentary rock fragments. Volcanic detritus is ubiquitous throughout the formation but increases in abundance toward the top of the formation and the Crowsnest Member (Mellon, 1967).

The interbedded sedimentary and pyroclastic detritus at the top of the Mill Creek Formation is included in the formation as the Crowsnest Member because of vertical and lateral gradational contacts with the

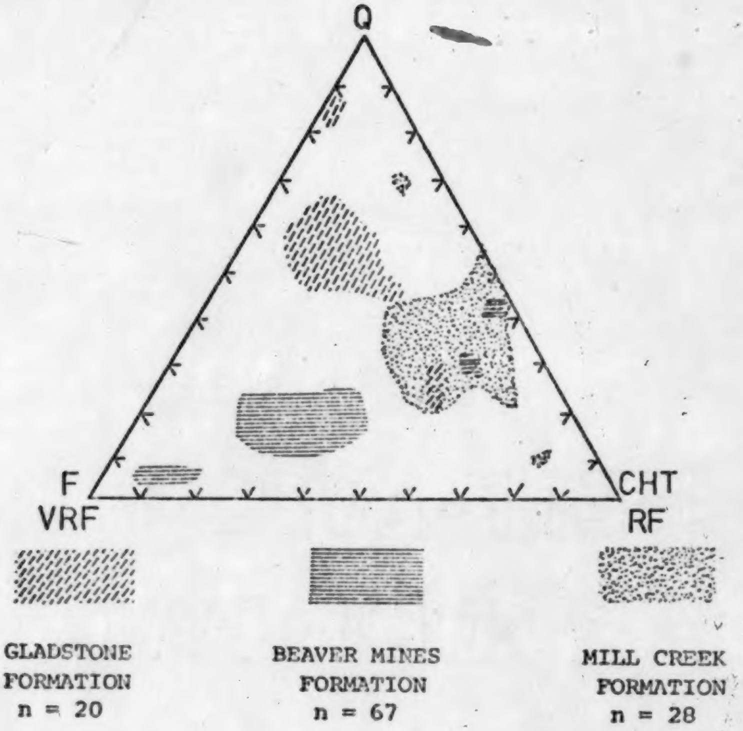


Figure 3-1. Tenary diagram showing the relative proportions of common detrital constituents in modally analysed sandstones of the Blairmore Group (modified from Mellon, 1967; Gladstone Formation, Figure 31; Beaver Mines Formation, Figure 34; Mill Creek Formation, Figure 45). (Q) quartz, (CHT) chert, (RF) nonvolcanic rock fragments, (VRF) volcanic rock fragments, (F) feldspar.

lower sedimentary part of the formation (Mellon, 1967). The member attains its greatest thickness near Coleman, Alberta but thins quickly in all directions and is not present east of the Foothills nor north of the Oldman River in Township 12.

The nature of the pyroclastics indicates an explosive origin of the material from a differentiated alkali trachyte magma (Ferguson, et al. 1976). The Crowsnest Member tuffs and agglomerates contain volcanic rock fragments, potash feldspars, and lesser amounts of pyroxenes, garnets, plagioclase, and analcime, all of which are primary (Mellon, 1967; Pearce, 1970).

The Mill Creek Formation contains a dicotyledonous flora ("upper Blairmore flora") which is more advanced than the "lower Blairmore flora" (Mellon, 1967).

Age and correlation

Mellon (1967) presented a thorough discussion of floral and microfaunal distributions and age determinations in the Blairmore Group. Only the conclusions of that discussion will be presented here.

The basal part of the Kootenay Formation has been dated as Late Jurassic (Mellon, 1967) whereas the floral content of the upper part of the formation (Bell, 1956) suggests a Barremian (Lower Cretaceous) age. It is currently accepted that the Kootenay ranges in age from the Late Jurassic to the Early Cretaceous (Mellon, 1967).

The lower age limit of the "lower Blairmore flora" is indeterminant; in conjunction with microfaunal studies, a Lower to Middle Albian age is suggested for the "lower Blairmore flora" in the type area, and thus for the Gladstone and Beaver Mines Formation (Mellon and Wall, 1963; Mellon, 1967).

The "upper Blairmore flora" is found only in the Mill Creek Formation and so is restricted to southern Alberta. The age of this flora is late middle Albian or late Albian, thus establishing the upper age limit of the Blairmore Group in southern Alberta (Mellon, 1967).

Deposition of the Blackstone Formation which overlies the Blairmore Group began in the Cenomanian or Turonian. In the northern part of the study area, the Blackstone contains a fauna of the same age as the "Fish-scale" marker which has long been considered the Lower-Upper Cretaceous boundary. In the southern part of the area, the base of the Blackstone Formation is somewhat younger (Mellon, 1967).

Correlative units of the Blairmore Group are presented in Figure 3-2.

The presence of coal seams in the Lower Blairmore of the central and northern Foothills prompted McKay (1930) to divide the Blairmore Group into the Cadomin, Luscar, and Mountain Park Formations. In the same area, the lateral equivalent of the underlying Kootenay Formation is the Nikanassin Formation which does not contain coal.

Several sets of formational names have been proposed for Lower Cretaceous strata for various parts of the Plains. In southern Alberta the lateral equivalent of the Blairmore Group is the Mannville Group. The Lower Mannville is correlative to the Gladstone Formation and contains a lower Sunburst Formation and an upper "Calcareous Member" (Mellon, 1967) or "Ostracode zone" (Brown, 1976). The upper Mannville is equivalent to the Beaver Mines Formation, and the Mill Creek Formation laterally intertongues with the lowermost marine shales of the Colorado Group (Mellon, 1967).

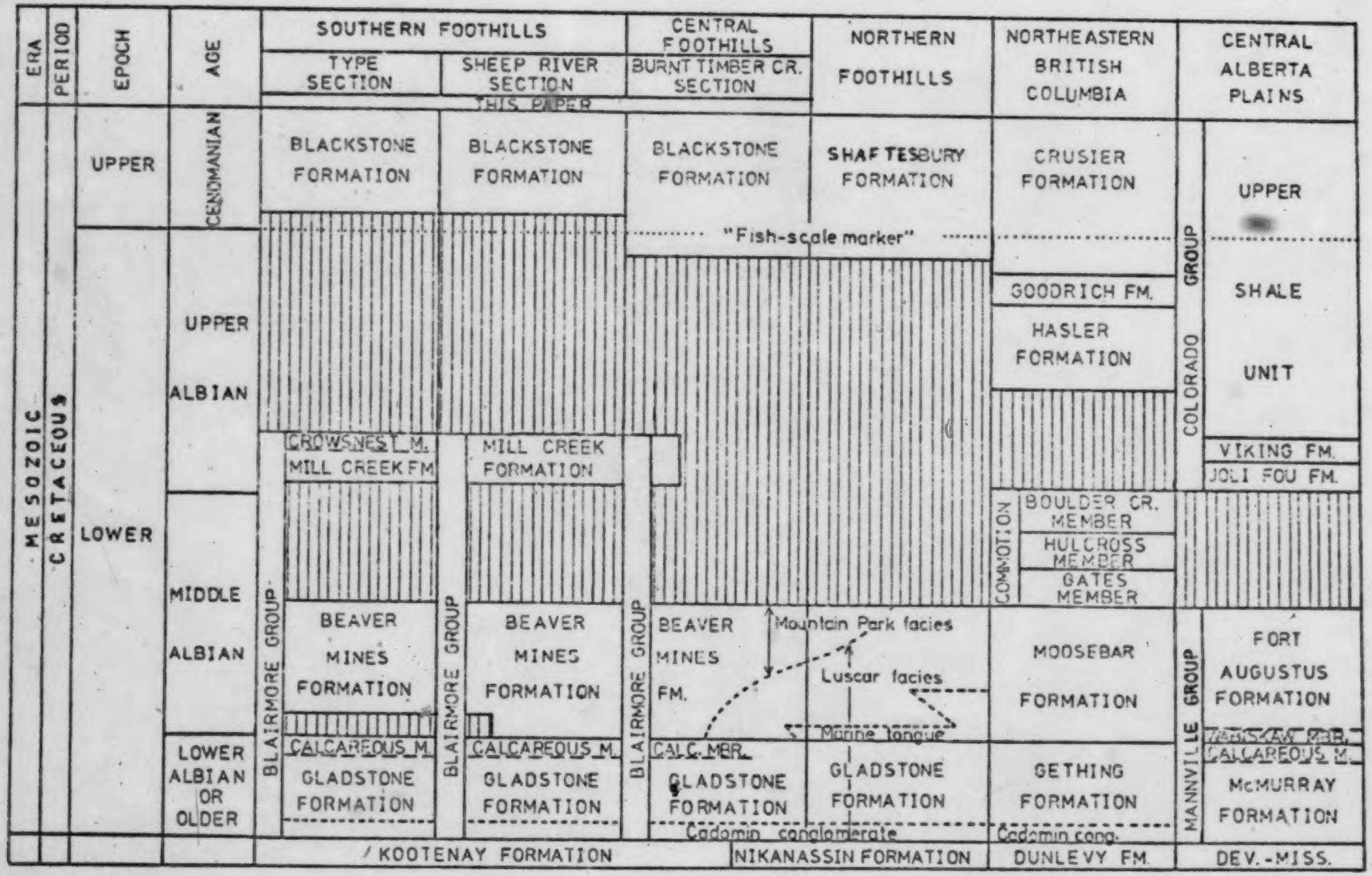

ERA
PERIOD
EPOCH
AGE
SOUTHERN FOOTHILLS
TYPE SECTION
SHEEP RIVER SECTION
THIS PAPER
CENTRAL FOOTHILLS
BURNT TIMBER CR. SECTION
NORTHERN FOOTHILLS
NORTHEASTERN BRITISH COLUMBIA
CENTRAL ALBERTA PLAINS
MESOZOIC
CRETACEOUS
UPPER
LOWER
CENOMANIAN
UPPER ALBIAN
MIDDLE ALBIAN
LOWER ALBIAN OR OLDER
BLACKSTONE FORMATION
BLACKSTONE FORMATION
BLACKSTONE FORMATION
SHAFTESBURY FORMATION
CRUSIER FORMATION
"Fish-scale marker"
GOODRICH FM.
HASLER FORMATION
COLORADO GROUP
UPPER SHALE UNIT
VIKING FM.
JOLI FOU FM.
CROWSNEST M.
MILL CREEK FM
MILL CREEK FORMATION
COMMOTION
BOULDER CR. MEMBER
HULCROSS MEMBER
GATES MEMBER
BLAIRMORE GROUP
BLAIRMORE GROUP
BLAIRMORE GROUP
BEAVER MINES FORMATION
BEAVER MINES FORMATION
BEAVER MINES FM.
Mountain Park facies
Luscar facies
Marine tongue
MOOSEBAR FORMATION
MANNVILLE GROUP
FORT AUGUSTUS FORMATION
WABISKAW MBR.
CALCAREOUS M.
CALCAREOUS M
CALCAREOUS M
CALC. MBR.
GLADSTONE FORMATION
GLADSTONE FORMATION
GLADSTONE FORMATION
GLADSTONE FORMATION
GETHING FORMATION
McMURRAY FORMATION
Cadomin conglomerate
Cadomin cong.
KOOTENAY FORMATION
NIKANASSIN FORMATION
DUNLEVY FM.
DEV.-MISS.

Figure 3-2. Lower Cretaceous correlation chart, Alberta and British Columbia Foothills and Alberta Plains (after Mellon, 1967).

3.2 Paleogeography and tectonics

The Kootenay Formation is part of a molasse sequence which records the end of miogeosynclinal deposition which had continued in southern Alberta from the Late Precambrian to the Late Jurassic. Tectonism in the Western Cordillera caused uplift and the beginning of the building of a clastic wedge which spanned Late Jurassic to Early Tertiary time (Price and Mountjoy, 1970; Rapson, 1964). Dickinson (1976) used the term Rocky Mountain foreland basin for the area of this wedge east of the present Rocky Mountains; Stelck (1975) called the part of the foreland basin in southwestern Alberta the West Alberta Basin.

The Late Jurassic was marked by the earliest phase of the Columbian orogeny (Wheeler, 1967) and tectonic episodes continued sporadically into the mid-Teritary, culminating in the Laramide orogeny in the Eastern Cordillera (Price and Mountjoy, 1970; Wheeler, 1967).

Price and Mountjoy (1970) proposed a model in which intrusion in the Western Cordillera produced upwelling and lateral spreading in the upper crust. The lateral spreading in turn caused development of successive, subparallel thrust faults in the Rocky Mountains, each intrusion prompting a local surge of thrusting. Hiatuses within the clastic wedge represent quiescent periods for the faults.

With time, the thrusting migrated northeasterly, the clastic wedges becoming thicker to the west as they abutted against successively emergent thrust sheets (Price and Mountjoy, 1970). In relating the Columbian and Laramide orogenies to the active subduction of the Pacific plate under the North American plate, Dickinson (1976) called the area of thrusting the backarc fold-thrust belt.

The Late Jurassic-Early Cretaceous Kootenay Formation overlies the marine Fernie Formation. It records an easterly-prograding deltaic environment (Jansa, 1972) and reflects the first uplift in the west. Before the deposition of the basal Blairmore conglomerate, hundreds of metres of Kootenay sediment were eroded from the area of the present Foothills; the erosional surface had low relief and truncated successively older strata in an easterly direction (Norris, 1964; Rapson, 1964).

The basal Blairmore conglomerate, deposited by high-energy flow in a braided river-alluvial plain environment (Jansa, 1972; McLean, 1976) represents renewed uplift to the west. The rest of the Gladstone Formation is distinctly finer grained and was deposited in an alluvial floodplain and lake environment (Norris, 1964).

The Beaver Mines and Mill Creek Formations were also deposited in alluvial environments (Norris, 1964). The differences in sandstone petrography and the widespread hiatus between the two formations reflect pulses in uplift and variations in the source areas due to tectonism (Price and Mountjoy, 1970; Mellon, 1967).

A hiatus at the top of the Blairmore Group and the transgression of the Blackstone marine environment ended the continental deposition of the Late Jurassic-Early Cretaceous portion of the clastic wedge (Price and Mountjoy, 1970).

Mellon (1967) and Holter and Mellon (1972) have attempted to use the Gladstone and Beaver Mines formational names for the whole of the outcrop trend of the Blairmore and equivalent continental strate in the Foothills and to apply a facies model to the complete trend. A fluviatile depositional environment with interfingering marine tongues in the northern Foothills was invoked for the Blairmore Group and its lateral equivalents. In both papers (Mellon, 1967; Holter and Mellon, 1972), it was suggested that the Blairmore Group contains examples of cyclic sedimentation. Two "ideal" cycles were described for the Blairmore, one generated by migrating point bars in a meandering stream and the other by a prograding coastline. It was admitted that considerable variation was observed in the field and the variation was explained in a single sentence by the statement that the great variation could be expected in complex fluvial and deltaic environments.

Burwash, et al. (1964) divided the Precambrian basement under the plains of Alberta into a number of areas with the suggestion that the different areas had contrasting compositions and specific gravities. The line of division between two of the areas passes through Calgary in a northeasterly direction. Stelck (1975) has suggested that this differentiation of the basement is responsible for the restriction of the Mill Creek to the south of the Bow River. Discussions with Stelck (personal communication, 1976) provided the suggestion that the basement may have affected the deposition of more of the Blairmore Group than just the Mill Creek Formation. If this is the case, Mellon's (1967) and Holter and Mellon's (1972) assumption that controls on the deposition of the Blairmore extended over the length of the Foothills could be in error.

CHAPTER 4

GEOLOGY OF THE MEASURED SECTIONS

4.1 Introduction

The three sections of the Blairmore Group chosen for measurement were Mellon's type section (1967) southeast of the Crowsnest Pass region of Alberta, the section along the Sheep River, and the section on Burnt Timber Creek. These were chosen for the ease of access as well as length and completeness which were needed for use in the Markov analyses.

Figure 1-1 shows the general locations of the sections. Location descriptions of the sections are found in Figure 4-1. Appendix A consists of the detailed descriptions of the sections as measured for this study and Appendix B lists the sample descriptions coded for cluster analysis.

4.2 Type section

Location and access

The type section of the Blairmore Group (Mellon, 1967) is a composite section measured in three exposures along Mill Creek and its tributary, Gladstone Creek. The area is 20.6 km. (12.8 mi.) southeast of Burmis and 18.0 km. (11.2 mi.) southwest of Pincher Creek.

Mellon (1967) used three sections to obtain his type section, but due to the abnormally high, post-flooding level of the streams, Mellon's "eastern" section (the middle portion of the group) along Mill Creek was deleted. The lower 280 metres (919 feet) of the Blairmore

SECTION	D.L.S.S.	LONGITUDE	LATITUDE
Type section			
Gladstone Creek	W½ Sec.25, E½ Sec.26 Tp.5 R.2 W5M.	114° 8' 48" W	49° 22' 15" N to 49° 23' 11" N
Mill Creek	E½ Sec.13 Tp.5 R.2 W5M.	114° 9' 28" W to 113° 9' 39" W	49° 24' 26" N to 49° 24' 40" N
NTS map 82 G/8E GSC map 739A (Hage, 1943)			
Sheep River section	Sec.24 Tp.19 R.6 W5M Sec.19 Tp.19 R.5 W5M	114° 41' 46" W to 114° 41' 20" W	50° 37' 11" N to 50° 37' 29" N
NTS map 82 J/10E GSC map 827A (Hage, 1946)			
Burnt Timber Creek section	Tp.30 R.9 W5M	115° 9' 18" W to 115° 9' W	51° 36' N to 51° 35' 38" N
NTS map 82 O/11E GSC map 11-1965 (Ollerenshaw, 1966)			

Figure 4-1. Measured section locations.

Group was measured on Gladstone Creek in Sections 25 and 26 of Township 5, Range 2, West of the 5th Meridian. The portion of the section between 280 metres and 590 metres (1933 feet) above the base was located along Mill Creek in Section 13, Township 5, Range 2, W5M.

Access is available to Gladstone Creek along good secondary roads to the west of the stream and then by foot down to the stream. Secondary and private roads south and west of Beauvais Lake provide access to the eastern side of Mill Creek and from there one must walk to the section.

General geology

Imbricate thrust faulting has exposed the Blairmore Group in several parallel, elongate blocks in the area of the type section (Hage, 1943), where the strata dip to the southwest at 45° to 60°. Minor normal and thrust faults were observed in the section and compensation was made for them where necessary. The generalized geology and the section locations are shown in Figure 4-2 and Figure 4-3 is a graphic log of the section.

The section along Gladstone Creek began at the base of the 3 metre thick basal Blairmore conglomerate and sandstone which unconformably overlies the Kootenay Formation. The conglomerate grades upward into quartzose sandstone and varicloured claystones and siltstones, typical of the Gladstone Formation. The total thickness of the Gladstone is 77 metres (253 feet) with the top consisting of 14 metres (45 feet) of very fine grained limestone and calcareous claystone of the Calcareous Member.

The lower 204 metres (669 feet) of the Beaver Mines Formation was also measured along Gladstone Creek. The base of the formation was

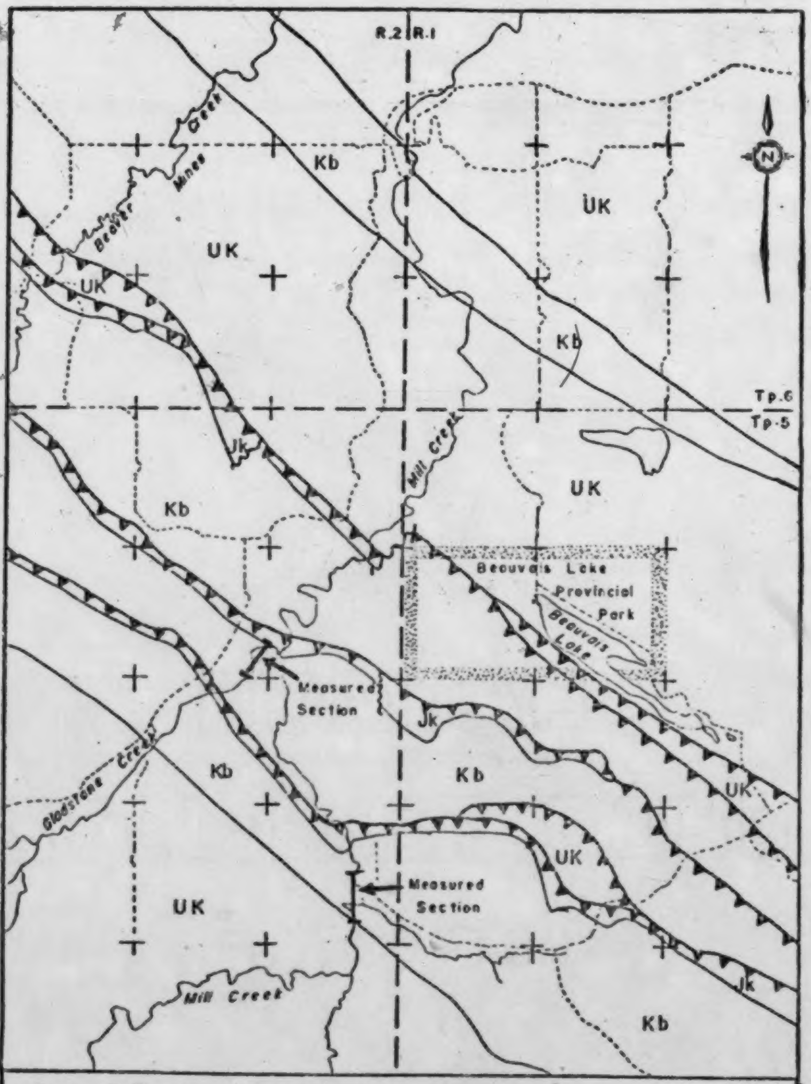

R.2
R.1
N
Beaver Mines Creek
Kb
UK
UK
UK
Kb
Tp.6
Tp.5
Jk
Mill Creek
Kb
UK
Beauvais Lake Provincial Park
Beauvais Lake
Measured Section
Jk
Gladstone Creek
Kb
Kb
UK
UK
Measured Section
UK
Jk
Mill Creek
Kb

Figure 4-2. Generalized geology of the type section area (after Hage,1943).

LEGEND

1 km

UK	Upper Cretaceous
Kb	Blairmore Group
Jk	Kootenay Formation

thrust fault
normal fault
geologic contact

measured section
township/range lines
+ section corner
roads
park boundary

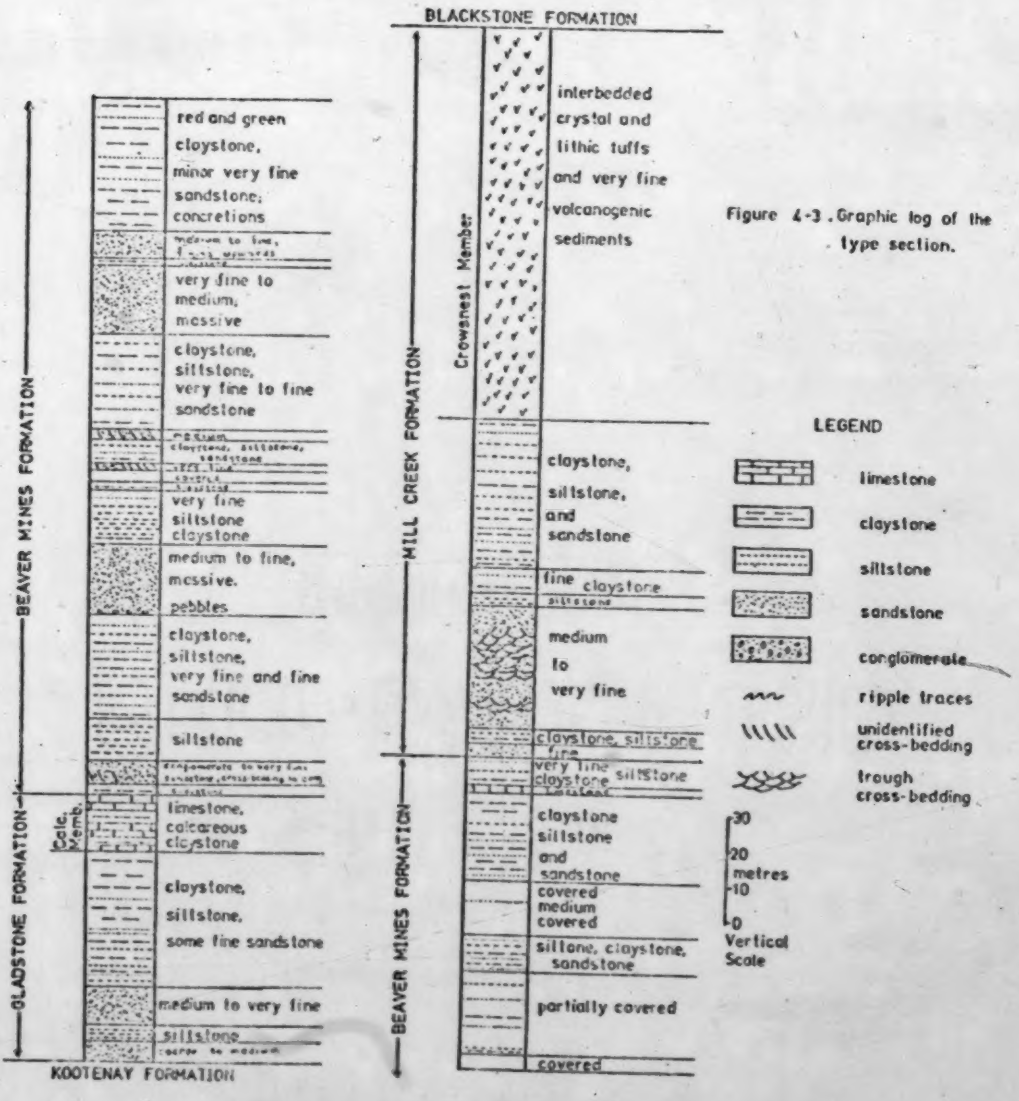

BLACKSTONE FORMATION
interbedded
crystal and
lithic tuffs
and very fine
volcanogenic
sediments
Crowsnest Member
MILL CREEK FORMATION
claystone,
siltstone,
and
sandstone
fine claystone
siltstone
medium
to
very fine
claystone, siltstone
fine
very fine
claystone siltstone
claystone
siltstone
and
sandstone
covered
medium
covered
siltone, claystone,
sandstone
partially covered
covered
BEAVER MINES FORMATION
red and green
claystone,
minor very fine
sandstone;
concretions
medium to fine,
very fine to
medium,
massive
claystone,
siltstone,
very fine to fine
sandstone
medium
claystone, siltstone,
sandstone
very fine
siltstone
claystone
medium to fine,
massive.
pebbles
claystone,
siltstone,
very fine and fine
sandstone
siltstone
conglomerate to very fine
sandstone, cross-bedding to conglomerate
GLADSTONE FORMATION
Calc. Memb.
limestone,
calcareous
claystone
claystone,
siltstone,
some fine sandstone
medium to very fine
siltstone
coarse to medium
KOOTENAY FORMATION
LEGEND
limestone
claystone
siltstone
sandstone
conglomerate
ripple traces
unidentified
cross-bedding
trough
cross-bedding
30
20
metres
10
0
Vertical
Scale

Figure 4-3. Graphic log of the type section.

set at the base of non-calcareous claystones and siltstones which overlie the Calcareous Member and which grade upward into a pebble conglomerate. The formation consists mainly of grey or red and green claystones interbedded with thin sandstone units. Thick, medium to coarse grained, green-grey, generally massive sandstones were observed at 61 and 151 metres above the base of the formation.

The upper 95 metres of the Beaver Mines Formation was measured in exposures along Mill Creek. The succession of interbedded claystones, siltstones, and sandstones continue for this part of the formation. The top of the formation was set at the top of 12 metres of interbedded claystone and fossiliferous limestone. This carbonate unit had not been described previously and is included in the Beaver Mines Formation since the overlying sandstones were distinctive and typical of the Mill Creek Formation. The total thickness of the Beaver Mines is 298 metres (978 feet).

The Mill Creek Formation, including the Crowsnest Member, was found to be 215 metres (705 feet) thick. The base of the volcanic rocks of the Crowsnest Member was gradational and was set at the base of the lowest, thick, massive tuff, 89 metres above the top of the Beaver Mines Formation. The lower portion of the formation consists of light-colored sandstones and grey or mottled red and green claystones and siltstones. Particularly thick, cross-bedded sandstones were observed 18 and 42 metres above the base of the formation.

The Crowsnest Member, 125 metres thick, consists predominantly of volcanic tuffs and agglomerates. Many of the volcanic units exhibit evidence of reworking by water and are interbedded with claystones and siltstones.

Overlying the Mill Creek Formation are the easily recognized, fissile shales of the Blackstone Formation.

The type section is fairly typical of the three sections discussed here in terms of sedimentary structures. Trough cross-stratification was observed once in a conglomerate, three times in medium grained sandstone, and twice in each of fine and very fine grained sandstone. An unidentified type of cross-stratification was observed only three times and ripple marks were noted five times.

Ten occurrences of calcareous concretions were noted. These were mainly contained within claystone units and were not within close vertical proximity to any thick sandstone. Plant fragments were observed in the finer grained lithologies but most of the sandstones contained a detrital fraction of carbonaceous material. Mud clasts were rare in abundance and recognized only in the finest grained lithologies.

Lithotypes

The 261 samples collected from the type section were described and coded for cluster analysis according to the detailed descrition outlined in the "Sample description" portion of Chapter 2. The number of attribute states used in the analysis was 130, and the resultant dendrograph is shown in Figure 4-4.

The second cluster analysis which excluded the petrographic data uses 244 samples described by 69 attribute states. As stated in Chapter 2, the two cluster analysis methods grouped the samples in a very similar way and the second clustering (Figure 4-5) was used to code the section for further study.

The difference in the number of samples between the two analyses was due to the elimination of the limestone samples from the second analysis. Too few carbonate units and transitions from carbonate to other lithologies were present in the section for meaningful inclusion in Markov analysis and hence they were deleted.

The descriptions of the main clusters of samples or the lithotypes are as follows:

Lithotype T1: mean grain size of very fine sand with a range of silt to fine sand; subangular to subrounded clasts; poor to moderate sorting; green-grey, weathering grey; sharp to gradational lower contact; rarely cross bedded.

Lithotype T2: mean grain size of silt, range of clay to very fine sand; angular to subangular clasts; moderate sorting; green-grey to grey, weathering grey; sharp lower contact; rarely laminated.

Lithotype T3: mean grain size of clay, range of clay to silt; moderately to well sorted; red and green, grey, or green-grey, weathering red and green or grey; sharp to gradational lower contact; local concretions, laminations, and plant fragments.

Lithotype T4: mean grain size of fine sand, ranging from very fine to medium sand; subangular to subrounded clasts; moderate to poor sorting; green grey, weathering the same; sharp lower contact; rare bioturbation.

Lithotype T5: mean grain size of medium sand with a range of very fine to medium sand; subangular to subrounded clasts; moderately to well sorted; green grey to grey, weathering the same; sharp to gradational lower contact, locally erosional; locally abundant cross-bedding (mainly in the Mill Creek Formation).

In addition to clustering the whole section, the samples from the Beaver Mines Formation were used as input to a cluster analysis for use in a Markov analysis of that formation alone. The number of samples totalled 179 and the attribute states 69. Figure 4-6 depicts the dendrograph of this clustering and the lithtype descriptions follow.

Lithotype TBM1: mean grain size of silt, range of clay to sit; angular to subangular clasts; moderate to poor sorting; dark green-grey, weathering grey; sharp to gradational lower contact; occasionally laminated.

Lithotype TBM2: mean grain size of very fine sand, range of clay to fine sand; subangular to subrounded clasts; poor to moderate sorting; green-grey, weathering the same; sharp to gradational lower contact; rare cross-bedding and plant fragments.

Lithotype TBM3: mean grain size of fine sand, range of very fine to medium sand; poor to moderate sorting; green-grey, weathering the same; sharp lower contact.

Lithotype TBM4: mean grain size of medium to coarse sand, range of fine to very coarse sand; subangular to subrounded clasts; moderate to poor sorting; green-grey, weathering the same; sharp to gradational lower contact.

Lithotype TBM5: silty clay, grain size range of clay to silt; moderately to well sorted; green-grey or red and green, weathering grey or red and green; sharp lower contact.

Lithotype TBM6: grain size of clay, range within clay size; well sorted; grey to green-grey, weathering grey; gradational to sharp lower contact; occasional plant fragments and concretions.

4.3 Sheep River section

Location and access

The Sheep River section was measured in one continuous exposure along the Sheep River in the Rocky Mountain Foothills of southwestern Alberta. The area is located 30.9 km. (19.2 mi.) west of Turner Valley and 69.5 km. (43.2 mi.) southwest of Calgary. Specifically, the section is in Section 24, Township 19, Range 6, W5M and Section 19, Township 19, Range 5, W5M.

Forestry roads running west from Highway 22 at Turner Valley provide access to the north bank of the Sheep River; from the road one must walk down to the section.

General geology

The Blairmore Group in the Sheep River section crops out on the east limb of an anticline with dips ranging between 70° SW (overturned) and 30° NE (Hage, 1946). The sections contain the complete Gladstone Formation, whereas the Beaver Mines and the Mill Creek Formations both have faulted upper contacts. The complete section is 493 metres (1618 feet) thick. See Figure 4-7 for a generalized geological map and section location and Figure 4-8 for a graphic log of the section.

The Gladstone Formation is 167 metres thick and unconformably overlies the Jurassic-Cretaceous Kootenay Formation. At the base of the Gladstone is a 4.5 metre thick chert-quartzite-pebble-conglomerate. Between the conglomerate and the uppermost Calcareous Member, the formation consists of interbedded grey claystone, siltstones, and medium grey, fine to medium grained sandstones. The sandstone units are less than five metres thick and generally massive. The very fine sandstones,

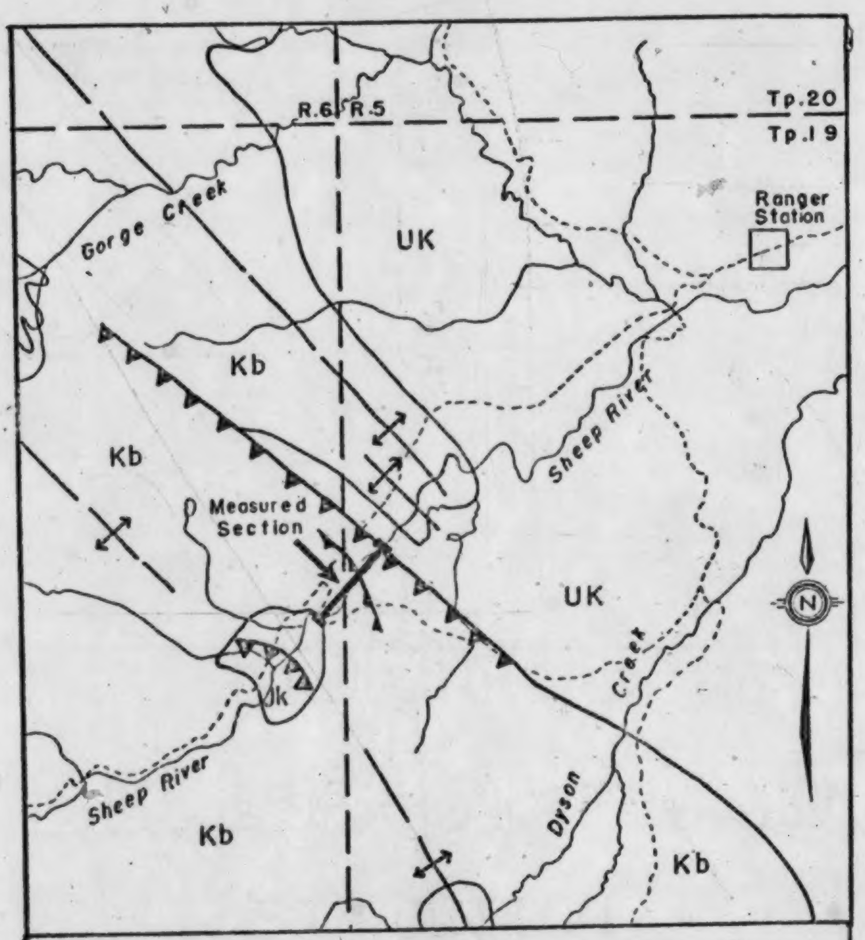

R.6
R.5
Tp.20
Tp.19
Ranger Station
Gorge Creek
UK
Kb
Kb
Sheep River
Measured Section
UK
Dyson Creek
Jk
Sheep River
Kb
Kb
N

Figure 4-7. Generalized geology of the Sheep River section area (after Hage, 1946).

LEGEND

1 km

UK Upper Cretaceous

Kb Blairmore Group

Jk Kootenay Formation

thrust fault

geologic contact

anticlinal axis

measured section

township/range line

road

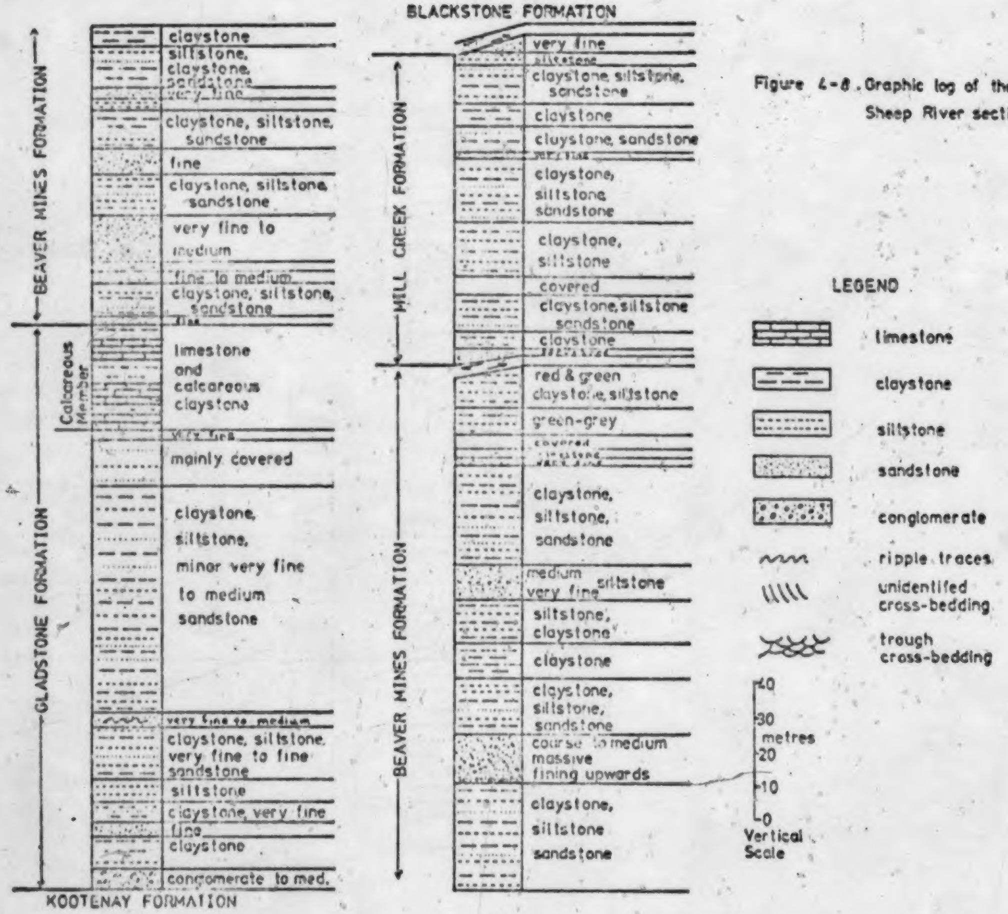

BEAVER MINES FORMATION
claystone
siltstone,
claystone,
sandstone
very fine
claystone, siltstone,
sandstone
fine
claystone, siltstone,
sandstone
very fine to
medium
fine to medium
claystone, siltstone,
sandstone
fine
GLADSTONE FORMATION
Calcareous
Member
limestone
and
calcareous
claystone
very fine
mainly covered
claystone,
siltstone,
minor very fine
to medium
sandstone
very fine to medium
claystone, siltstone,
very fine to fine
sandstone
siltstone
claystone, very fine
fine
claystone
conglomerate to med.
KOOTENAY FORMATION
BLACKSTONE FORMATION
HILL CREEK FORMATION
very fine
siltstone
claystone, siltstone,
sandstone
claystone
claystone, sandstone
claystone,
siltstone
sandstone
claystone,
siltstone
covered
claystone, siltstone
sandstone
claystone
BEAVER MINES FORMATION
red & green
claystone, siltstone
green-grey
covered
claystone,
siltstone,
sandstone
medium
very fine
siltstone
siltstone,
claystone
claystone
claystone,
siltstone,
sandstone
course to medium
massive
fining upwards
claystone,
siltstone
sandstone
LEGEND
limestone
claystone
siltstone
sandstone
conglomerate
ripple traces
unidentifed
cross-bedding
trough
cross-bedding
40
30
20
10
0
metres
Vertical
Scale

Figure 4-8. Graphic log of the Sheep River section.

siltstones, and claystones are often bioturbated or contain concretions. Transported calcareous algal balls (identified by C.R. Stelck , 1975) were observed in a few claystone units near the base of the formation, well below the Calcareous Member.

The Calcareous Member occurs 134 metres above the base of the formation and was measured to be 30 metres thick. This is much thicker than previously published measurements (Mellon, 1967) and repetition due to faulting is suspected. The base of the Calcareous Member is at the base of the lowest limestone unit and the member consists of interbedded fresh-water limestone and calcareous claystones and siltstone.

The Beaver Mines Formation is 240 metres (786 feet) thick with the base at the lower contact of a fine grained massive sandstone which has tool marks at its base. The formation is made up of grey to green-grey claystones and siltstones interbedded with very fine grained to medium grained, grey to green-grey sandstones. The claystones and siltstones often contain plant fragments or concretions and are often bioturbated. The finest grained sandstones are generally massive and contain mud clasts. Particularly resistant, thick sandstone units were observed at 17 metres (13.5 metres thick), 43 metres (7.5 metres thick) and 118 metres (14.5 metres thick) above the base of the formation. These units are massive and consist of fine to coarse grained, green-grey sandstone.

The top of the exposed Beaver Mines Formation is in a 12.5 metre thick sequence of poorly exposed, red and green, interbedded claystone and siltstone. This unit was interpreted as a fault zone in which the Beaver Mines Formation had been thrust over the younger Mill Creek Formation. The faulting occurred near the actual top of the Beaver Mines Formation.

The Mill Creek in this section is faulted at both the top and bottom of the exposure. Between the faults, the formation is 89 metres (293 feet) thick. The base of the formation is at the base of the first grey sandstone overlying the red and green claystone unit previously described as containing the fault zone between the Beaver Mines and Mill Creek Formations. The rocks constituting the Mill Creek Formation are grey or red claystones interbedded with grey siltstones and medium grey, very fine to fine grained sandstones. Cross-bedding is rare but mud clasts and bioturbation were observed in the section but just downstream (Sec. 35, Tp. 19, R. 5, W5M) a 12.5 metre thick grey sandstone was observed on the crest of an anticline. The sandstone body has a horizontal extent of approximately 150 metres, laterally grading into claystones and siltstones, and was interpreted to be a fluvial channel deposit.

In the measured section, the top of the Mill Creek Formation is truncated by a fault along which the Mill Creek Formation was thrust over the Blackstone Formation.

The Blackstone Formation, consisting of black, fissile, marine shales, was observed downstream to be overlying the Mill Creek Formation.

A greater number of lithologic units were recognized in the Sheep River section and subsequently there are a greater number of sedimentary structures than in the type section. Both large- and small-scale trough cross-stratification were recognized. The large-scale forms were confined to fine and coarser grained sandstones, whereas the smaller trough cross-beds were in siltstone, very fine grained sandstone, and medium grained sandstone. Unidentifiable types of cross-stratification were all small in scale and were found in fine grained sandstone to siltstone, probably generated by ripples. Identified ripple marks were mainly confined to the finest lithologies.

Plant remains were found in all lithologies, however, they were most common in claystone. The occurrences of calcareous concretions and bioturbation were restricted to claystone to very fine grained sandstone, claystone again having the greatest abundance. Mud clasts were present in all lithologies.

Lithotypes

The 368 samples collected from the Sheep River section were clustered using 77 attribute states by the method outlined in Chapter 2 for the Sheep River and Burnt Timber Creek sections. The descriptions of the lithotypes derived from the dendrograph for the complete section (Figure 4-9) are as follows:

Lithotype S1: grain size range of very fine sand to conglomerate, dominated by very fine grained sandstone; angular to subangular clasts; poorly to moderately sorted; sharp to gradational base; 8% to 20% dark minerals; 2% to 10% carbonaceous material; rare plant remains; dark green-grey to grey, weathering green-grey to grey.

Lithotype S2: mean grain size of silt, range of clay to medium sand; angular to subangular clasts; moderate sorting; 1% to 10% dark minerals; 1% to 15% carbonaceous material; rare plant remains; sharp to gradational base; dark green-grey, weathering green-grey or grey.

Lithotype S3: mean grain size of clay, range of clay to silt; poor to moderate sorting; sharp to gradational lower contact; very rare plant remains; dark green-grey to medium grey, weathering grey.

Lithotype S4: mean grain size of silt, range of very fine sand to clay; poor to moderate sorting; sharp lower contact; 0% to 4% dark minerals; 0% to 2% carbonaceous material; no plant remains; light to medium grey, weathering grey.

Lithotype S5: mean grain size of clay, range of clay to fine sand; moderate sorting; 0% to 6% carbonaceous material; sharp to gradational lower contact; occasional plant remains; black to grey, weathering grey.

Lithotype S6: mean grain size of clay, no range; moderately to well sorted; 0% to 2% carbonaceous material; rare plant remains; sharp lower contact; dark green-grey to grey, weathering grey.

A cluster analysis of the samples from only the Beaver Mines Formation in the Sheep River section was also performed with 167 samples and 77 attribute states. The lithotypes chosen from the resultant dendrograph (Figure 4-10) are:

Lithotype SBM1: mean grain size of very fine sand, range of silt to fine sand; angular to subangular clasts; poorly sorted; 8% to 20% dark minerals; 3% to 10% carbonaceous material; sharp to gradational base; dark green-grey, weathering grey.

Lithotype SBM2: mean grain size of fine sand, range of very fine to medium sand; angular to subangular clasts; poor sorting; 10% to 20% dark minerals; 0% to 5% carbonaceous material; sharp to gradational lower contact; dark green-grey, weathering grey or green-grey.

Lithotype SBM3: mean grain size of medium sand, range of fine to coarse sand; angular to subangular clasts; poor sorting; 5% to 20% dark minerals; 1% to 5% carbonaceous material; rare plant remains; gradational to sharp lower contact; dark green-grey, weathering grey.

Lithotype SBM4: mean grain size of silt, range of clay to silt; angular clasts; poorly sorted, 5% dark minerals; 5% carbonaceous material; gradational to sharp lower contact; dark green-grey, weathering grey.

Lithotype SBM5: mean grain size of silt, range of clay to silt; very angular to angular clasts; poorly sorted; 10% to 20% dark minerals; 10% carbonaceous material; occasional plant remains; sharp lower contact; dark green-grey, weathering grey or green-grey.

Lithotype SBM6: grain size of clay; well sorted; 0% to 5% carbonaceous material; sharp base; occasional plant remains; dark green-grey, weathering grey.

Lithotype SBM7: mean grain size of clay, range of clay to silt; poor to moderate sorting; 7% carbonaceous material; gradational to sharp lower contact; dark green-grey, weathering grey.

4.4 Burnt Timber Creek section

Location and access

Part of the Blairmore Group was measured along Burnt Timber Creek in the south-central Foothills of Alberta. The section is 42.5 km. (26.4 mi.) southwest of Sundre and 96.5 km. (60 mi.) northwest of Calgary. The exposure is in Township 30, Range 9, W5M, 6.5 km. (4 mi.) upstream of the confluence of the Red Deer River and Burnt Timber Creek and along the main branch of the stream.

Access to the section is available by the Forestry Trunk Road to where the road crosses the creek. A trail along the north side of Burnt Timber Creek leads to the base of the section 1.3 km. east of the trunk road.

General geology

The northwesterly-trending Burnt Timber Thrust has Jurassic and Cretaceous formations (including the Blairmore) exposed in its hanging wall (Ollerenshaw, 1966). The strata dip to the southwest at angles between 26° and 45°. Locally, there is severe deformation by folding and faulting due to the proximity of major thrust faults. See Figure 4-11 for the generalized geology and measured section location and Figure 4-12 for a graphic log of the section.

The lowest formation of the Blairmore Group, the Gladstone, is poorly exposed along Burnt Timber Creek. At the base of the formation is a 10 to 15 metre thick chert-quartzite conglomerate which lies with an erosional unconformity upon the Jurassic-Cretaceous Kootenay Formation. The part of the formation between the basal conglomerate and the Calcareous Member is rarely exposed and no attempt to measure the formation or to estimate the total thickness was made. The Calcareous Member was recognized in poor exposures but was severely folded and sheared and no measurement was made.

The Beaver Mines Formation was the only portion of the group measured in detail at this locality and was found to be 238 metres (782 feet) thick. The contact with the underlying Gladstone Formation was partially covered so measurement began at the base of a thick, fine grained, green-grey sandstone. The formation consists of interbedded grey to green-grey claystones, siltstones, and very fine sandstones with occasional coarser sandy units. These moderately thin sandy units (less than 2 metres) alternate between being massive and being cross-stratified and occasionally contain mud clasts and plant remains. The section contains a number of thick, resistant units which are either fine to

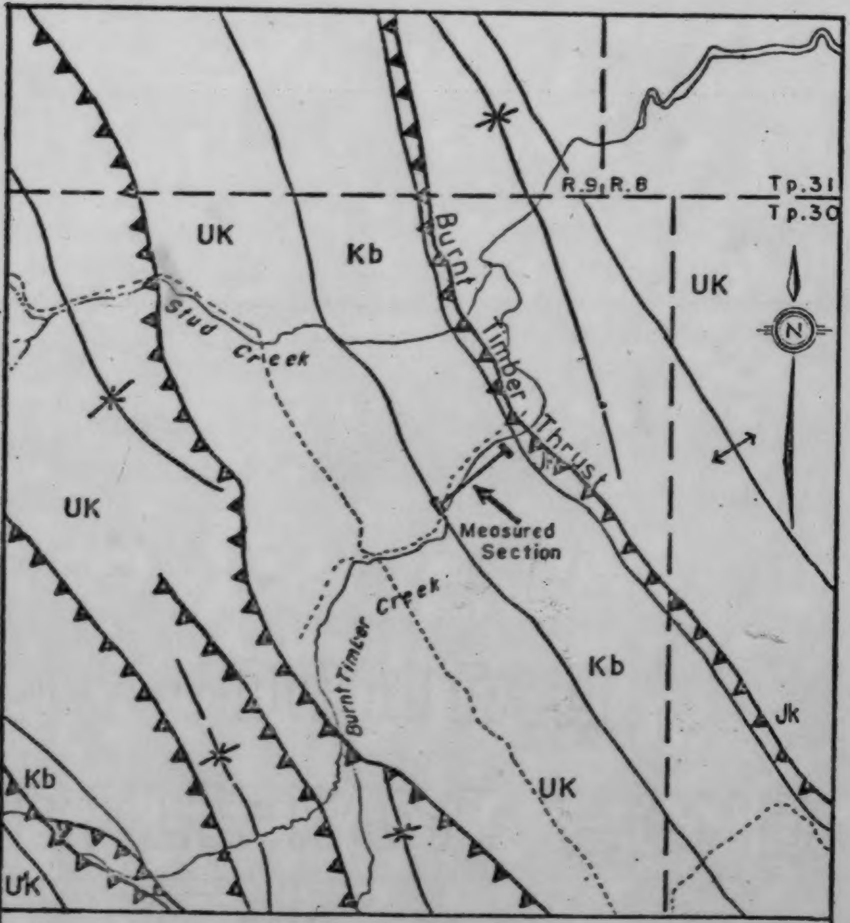

R.9
R.8
Tp.31
Tp.30
UK
Kb
Burnt Timber Thrust
UK
N
Stud Creek
UK
Measured Section
Timber Creek
Burnt Timber Creek
Kb
Jk
Kb
UK
UK

Figure 4-11. Generalized geology of the Burnt Timber Creek section area (after Ollerenshaw, 1966)

LEGEND

1 km

UK	Upper Cretaceous
Kb	Blairmore Group
Jk	Kootenay Formation

▼▼	thrust fault	⊢⊣	measured section
—	geologic contact	— — —	township/range line
↕	anticlinal axis	--------	road
✳	synclinal axis		

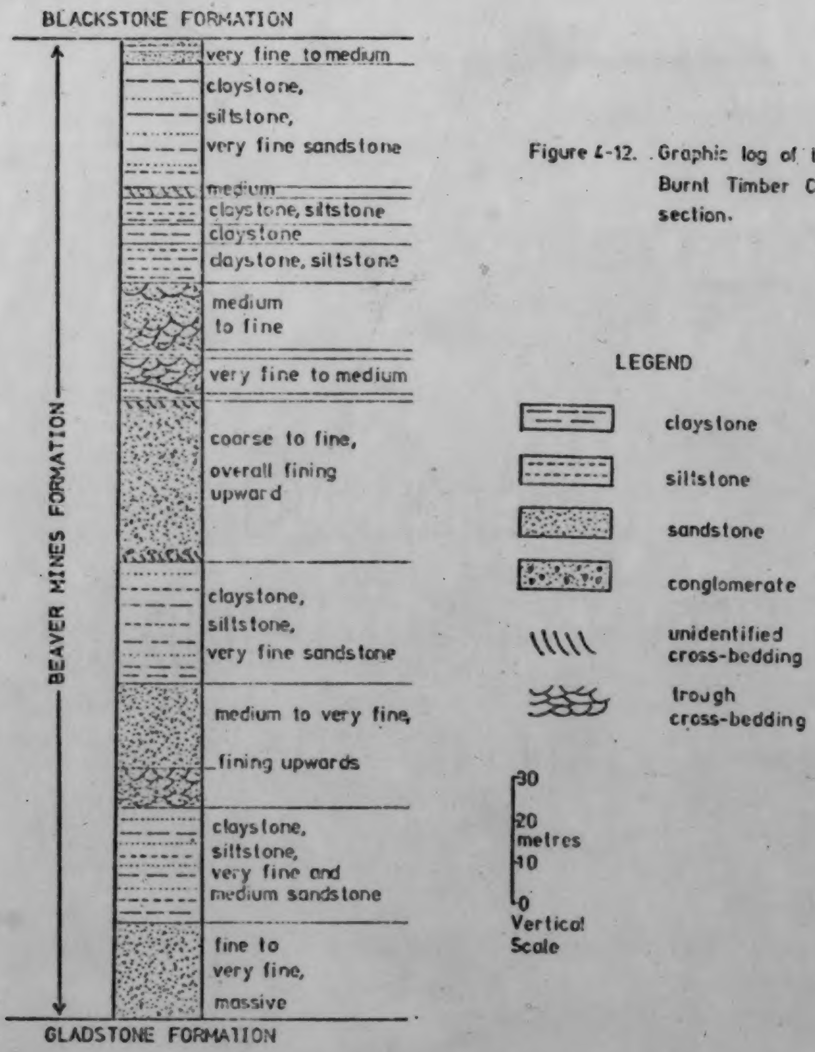

BLACKSTONE FORMATION
very fine to medium
claystone,
siltstone,
very fine sandstone
medium
claystone, siltstone
claystone
claystone, siltstone
medium
to fine
very fine to medium
coarse to fine,
overall fining
upward
claystone,
siltstone,
very fine sandstone
medium to very fine,
fining upwards
claystone,
siltstone,
very fine and
medium sandstone
fine to
very fine,
massive
GLADSTONE FORMATION
BEAVER MINES FORMATION
LEGEND
claystone
siltstone
sandstone
conglomerate
unidentified
cross-bedding
trough
cross-bedding
30
20
metres
10
0
Vertical
Scale

Figure 4-12. Graphic log of the Burnt Timber Creek section.

medium grained, cross-bedded sandstones or coarse to medium grained, massive sandstones.

The Mill Creek Formation does not appear in the stratigraphic section in this part of the Foothills (Mellon, 1967), thus the Blackstone Formation rests directly upon the Beaver Mines Formation. The actual contact between these two formations was poorly exposed on Burnt Timber Creek. Below the typical black, fissile shales of the Blackstone Formation is a black-and-white banded sandstone which overlies a dark grey shale. Mellon (1967) stated this shale contains a "Fish-scales" fauna which indicates a Blackstone age for the shale and overlying units. Therefore, the top of the Beaver Mines Formation is placed at the top of the very fine grained sandstone beneath the dark grey shale.

In the Beaver Mines Formation in the Burnt Timber Creek section, large-scale trough cross-stratification was observed in very fine to coarse grained sandstone. Four occurrences of large-scale unidentified cross-stratification were noted in fine to medium grained sandstone. Seven occurrences of small-scale cross-bedding of an unidentified type were noted in the lithologies of siltstone to fine grained sandstone. Ripple marks were found only in siltstone. One occurrence of load casts were seen in a very fine grained sandstone.

Plant debris and mud clasts were found in all types of lithologies. Bioturbation was restricted to claystones and siltstones. One occurrence of calcareous concretions was noted in a claystone unit.

Lithotypes

A total of 207 samples from the Burnt Timber Creek section were described by 77 attribute states in the same format as that used for the Sheep River section and were subjected to cluster analysis. The lithotypes chosen from the resultant dendrograph (Figure 4-13) have the following description:

Lithotype B1: grain size of medium to coarse sand, range of fine to very coarse sand; angular clasts; poorly sorted; 8% to 15% dark minerals; 1% to 5% carbonaceous material; sharp to gradational lower contact; rare plant remains; locally abundant large trough cross-stratification; dark green-grey, weathering green-grey.

Lithotype B2: grain size of fine to medium sand, range same; angular clasts; poorly sorted; 8% to 12% dark minerals; 1% to 3% carbonaceous material; very rare plant remains; green-grey, weathering grey; abundant large-scale cross-stratification; sharp to gradational lower contact.

Lithotype B3: mean grain size of very fine sand, range of silt to fine sand; angular clasts; poor to moderate sorting; 5% to 12% dark minerals, 1% to 5% carbonaceous material; rare plant remains; dark green-grey, weathering grey to green-grey; rare cross-bedding; sharp to gradational lower contact.

Lithotype B4: mean grain size of silt, range of clay to very fine sand; moderate to poor sorting; 3% to 7% carbonaceous material; no plant remains; dark green-grey to dark grey, weathering green-grey or grey; gradational to sharp lower contact.

Lithotype B5: mean grain size of clay, range of clay to very fine sand; well to moderately sorted; sharp lower contact; very rare plant remains; dark grey to dark green-grey, weathering grey to green-grey.

4.5 Summary

A summary comparison of the lithotypes is presented in Figure 4-14 where the grain size average and range is plotted for each of the lithotypes described above.

For use in Markov analyses and for sedimentological interpretation, the grain size of the rocks was considered very important. Hence, the attribute of sample grain size was given twice the normal weight in the coding for cluster analysis. From the above descriptions of the lithotypes and from Figure 4-14, it can be seen that grain size was the attribute with the most influence on the clustering of the samples. This is partially a function of the doubled weight as well as the similarity among the samples of the same grain size. The restriction of keeping the number of lithotypes small for valid Markov analyses did not allow greater differentiation of the sample groupings which actually was possible from the dendrographs.

The lithotypes of the Beaver Mines Formation of the Sheep River section are somewhat unique in this set of analyses. The abundance of claystones and siltstones relative to the coarser grained units permitted finer distinctions to be made among the finest grained lithogies. Thus, seven lithotypes were identified for this set of samples with four of them being made up of claystone and siltstone. Lithotypes SBM4 and SBM5 have the same grain size average and range and may be distinguished by the presence of plant debris in SBM5 and the absence of the same in SBM4.

Because of the dominating influence of grain size in the clustering of the samples, the procedure of cluster analysis is of limited value in this type of study. The identification of the units by grain

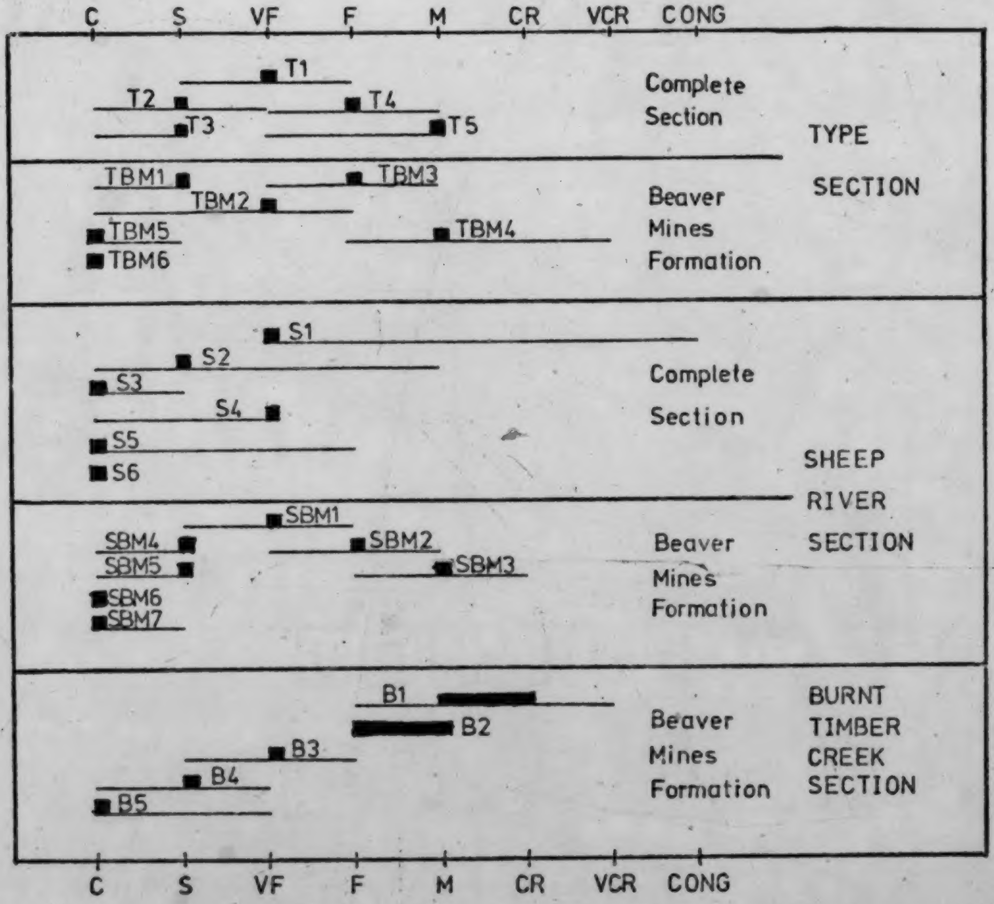


Figure 4-14. Summary diagram of the lithotypes used. Comparisons are based on the grain size of the lithotypes. The solid black areas represent the average grain size, the lines the grain size range.

size can easily be done by a geologist without the time- and money-consuming process of describing and coding each sample and subjecting sets of samples to cluster analysis. The two methods of classification used in this study produced essentially the same results and it is strongly suggested that cluster analysis does not add substantially to this type of investigation.

The most obvious feature of classification by grain size alone is that simple, short descriptive terms are all that are necessary for a readily understood discussion. Using lithotypes, a major stumbling block is the difficulty in discovering what each lithotype represents and remembering the distinguishing attributes among them all. Ethier (1970) arrived at the same conclusion and commented that the procedure was an interesting comparison between human and machine logic.

As stated above, the lithotypes generated in this study were very similar to the lithologic units identified by grain size alone. Because of this the lithotypes were used only in the Markov analyses. Sedimentological discussions (Chapter 6) used only the grain size lithologic units which are more easily understood and which represented the same results as the lithotypes.

CHAPTER 5

MARKOV CHAIN ANALYSES

5.1 Introduction

The testing done for the presence or absence of a Markov property in the measured sections used the embedded Markov chain model. The analysis was done on the complete Blairmore Group for the type section and the Sheep River section. Two analyses were done for each section; one used units defined by grain size and the other units defined by the lithotypes described in Chapter 4.

Because the Beaver Mines Formation forms the bulk of the Blairmore Group, it was tested independently. This was done for the type section, the Sheep River section and the Burnt Timber Creek section, again, both by grain size and by lithotypes.

A test was made in all the combinations mentioned above for the presence of Schwarzacher's (1969) definition of geological cyclicity which was discussed in Chapter 2. This was done by structuring the transition probability matrices as regular Markov chains at 1 and 2 metre intervals.

Section 5.2 contains the results from the studies of the complete Blairmore Group. In one subsection, the results of the tests for Markov dependency and geological cyclicity are presented for the two sections coded according to grain size and a second section contains the results for the same sections coded by lithotypes. Section 5.3 has the same format and contains the results for the Beaver Mines Formation.

The transition probability and difference matrices of the embedded chains are included in the text and also with the respective transition frequency and independent events matrices in Appendix C. The transition frequency and the transition probability matrices for the regular chains are all in Appendix C.

The question of stationarity in a Markovian sense is hard to answer for the Blairmore Group. In the type section and the Sheep River section, the transition probability matrices for the complete group and for the contained Beaver Mines Formation are very similar, suggesting that the sections are stationary.

The Beaver Mines Formation sections were divided into upper and lower halves and transition probability matrices were generated for each of these halves. The resultant matrices were distinctly different between the two halves of the same section. In order to test for stationarity, Schwarzacher (1975) suggested dividing a long section into equal fractions ". . . for as long as the data permit" (p. 111). It is concluded that the Beaver Mines Formation did not contain sufficient transitions to properly estimate probability matrices at any level less than the complete formation. Therefore, it was not possible to test the Beaver Mines Formation for stationarity by this method.

The Blairmore Group is considered stationary because of the similarity of the transition probability matrices of the complete group and its component formations. It must be noted that any interpretation dependent on this assumption is subject to modification if the Blairmore is later proven to be non-stationary.

5.2 Results for the Blairmore Group

In Chapter 2 it was stated that the thicknesses of all lithologies in a section must have a geometric distribution for the valid use of a regular Markov chain (Krumbein and Dacey, 1969). The histograms of lithologic unit thicknesses are presented for the type section in Figure 5-1 and for the Sheep River section in Figure 5-2. Even though the claystones, siltstones, and very fine grained sandstones approach but do not appear to resemble a geometric distribution, no tests were done on the distributions since the thicknesses of the medium and coarser grained sandstones and the fine grained sandstones definitely have non-geometric distributions. Since geometric distributions are not present for all lithologies, only the embedded Markov chain is valid (Krumbein and Dacey, 1969) and a regular chain may be used only to test for the presence of geological cyclicity (Schwarzacher, 1975).

Grain size lithogies

The sections were divided into lithologic units defined by the grain size of the unit: claystone (clay), siltstone (silt), very fine grained sandstone (v.f.), fine grained sandstone (fine), medium grained sandstone to conglomerate (med+). (The abbreviations in brackets are those used in following figures, tables and graphs.) The number of transitions from each lithology upward to every other lithology were counted and tabulated into transition frequency matrices. The counts were converted to probabilities and compiled into transition probability matrices. These were tested against the null hypothesis that a random process caused the vertical arrangement of the lithologic units.

In both the type section and the Sheep River section, the null

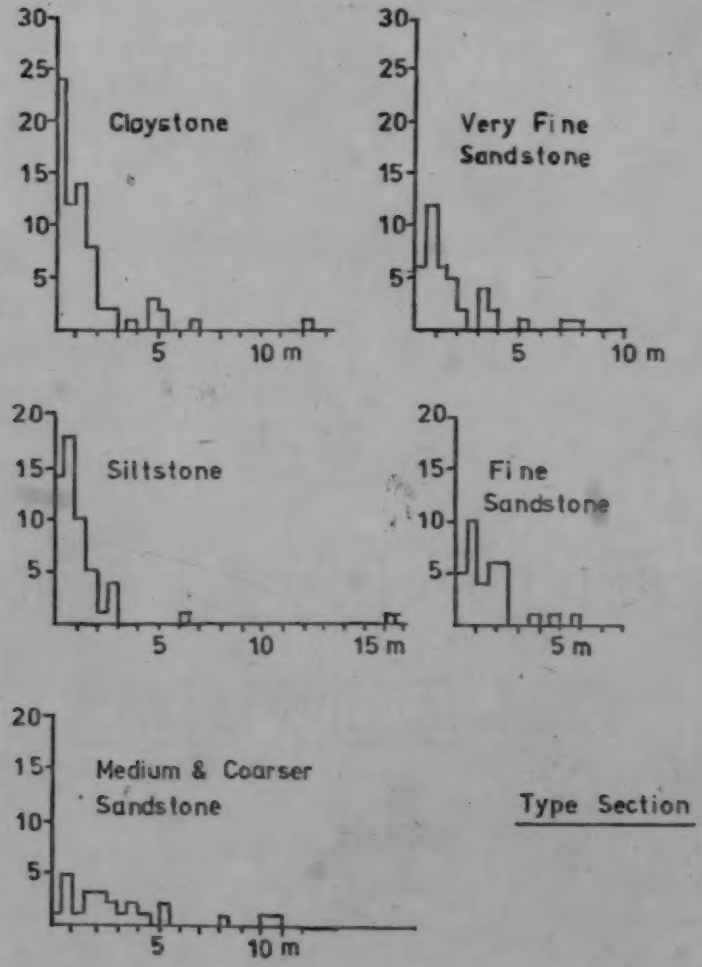


Figure 5-1. Frequency distributions of lithologic unit thicknesses of the complete Blairmore Group in the type section. Vertical axes in terms of the number of units.

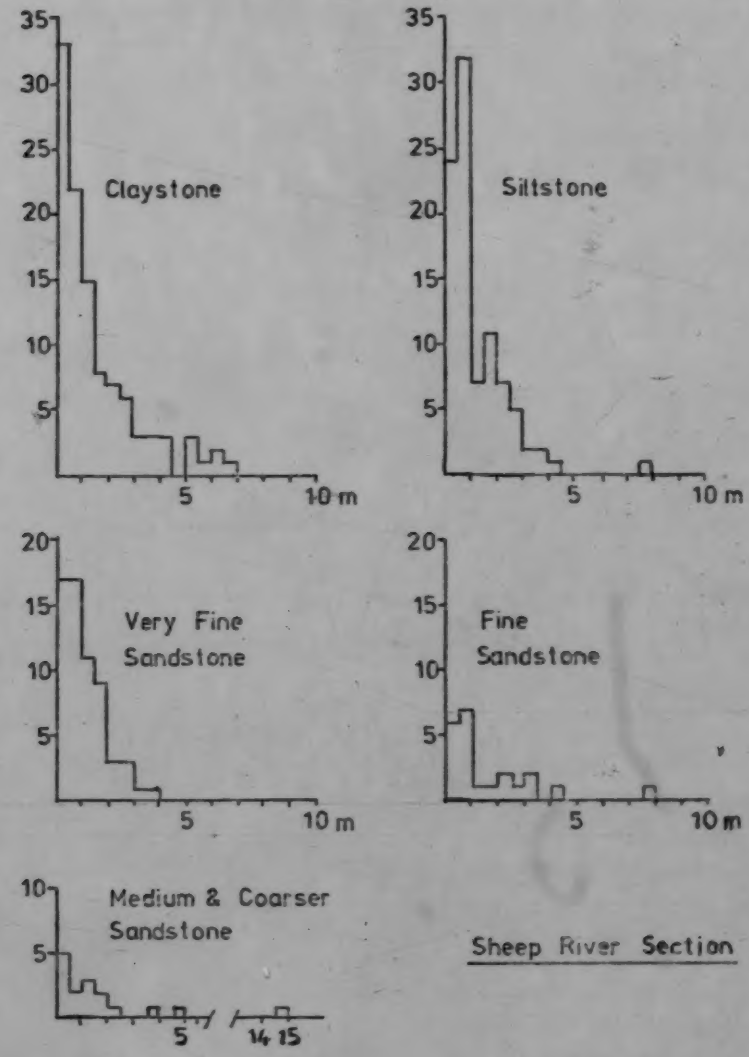


Figure 5-2. Frequency distributions of lithologic unit thicknesses of the complete Blairmore Group in the Sheep River section. Vertical axes are the number of units.

hypothesis was rejected in favour of the presence of a first-order Markov chain process at a 99.9% level of confidence. This can be seen by comparing the observed test statistics, 110.833 (type section) and 204.331 (Sheep River section) with the calculated χ^2 value of 31.3 with a 11 degrees of freedom.

Independent events matrices (Appendix C) were calculated for each of the sections and were subtracted from the respective transition probability matrices forming the difference matrices. The results are graphically presented as transition pattern diagrams; the lithology associations and the numerical values were taken from the difference matrices of the type section (Table 5-1) and the Sheep River section (Table 5-2) and are in Figure 5-3.

Transition probabilities were compiled at 1 metre and 2 metres sample intervals for the type section and the Sheep River section (see Appendix C for these and other matrices). The graphs of the transition probabilities of the elements of the principal diagonals of the matrices at successive powers of the matrices are presented in Figure 5-4 and 5-5. With these graphs are the eigenvalues of the respective matrices.

In both the type section and the Sheep River section, all of the transition probabilities approached a stable value by exponential curves, which should indicate that the Blairmore Group is non-oscillatory in these sections.

The eigenvalues for the 1 and 2 metre sample interval matrices of the Blairmore Group in the type section contained both positive real numbers and complex numbers. The existence of a complex eigenvalue suggests oscillatory behavior however, for the 1 metre intervals all of the elements decreased exponentially until the matrix reached its

Complete type section - Grain size lithologies

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.45	0.23	0.25	0.08
silt	0.51	0.00	0.27	0.10	0.12
v.f.	0.51	0.22	0.00	0.14	0.14
fine	0.48	0.11	0.26	0.00	0.15
med+	0.24	0.12	0.35	0.29	0.00

Difference matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.14	-0.07	0.02	-0.08
silt	0.08	0.00	0.01	-0.10	-0.10
v.f.	0.10	-0.05	0.00	-0.06	0.01
fine	0.11	-0.14	0.02	0.00	0.03
med+	-0.12	-0.11	0.12	0.12	0.00

$$\chi^2_{\text{observed}} = 110.833$$

$$\chi^2_{(.001,\ 11)\text{(calculated)}} = 31.3$$

Table 5-1. Transition probability and difference matrices for the type section grain size lithologies units for the complete Blairmore Group.

Complete Sheep River section - Grain size lithologies

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.57	0.30	0.10	0.03
silt	0.72	0.00	0.20	0.06	0.02
v.f.	0.47	0.41	0.00	0.02	0.10
fine	0.59	0.18	0.12	0.00	0.12
med+	0.31	0.38	0.15	0.15	0.00

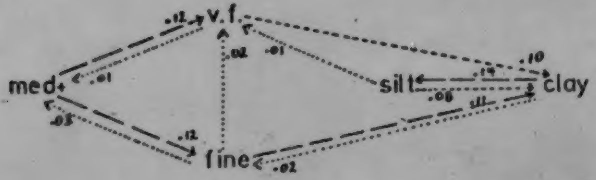
Difference matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.07	-0.01	-0.01	0.05
silt	0.15	0.00	-0.07	-0.03	-0.05
v.f.	0.00	0.02	0.00	-0.06	0.04
fine	0.18	-0.16	-0.08	0.00	0.07
med+	-0.09	0.05	-0.05	0.08	0.00

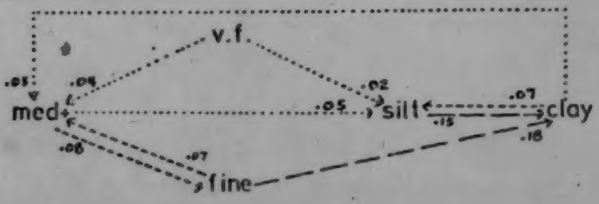
$$\chi^2_{\text{observed}} = 204.231$$

$$\chi^2_{(.001,\ 11)\,(\text{calculated})} = 31.3$$

Table 5-2. Transition probability and difference matrices for the complete Blairmore Group in the type section using grain size lithologies.


.11
v.f.
.02
.01
.10
.14
med
.01
silt
clay
.08
.03
.11
.12
fine
.02

A. Type section


v.f.
.05
.04
.02
.07
med
.05
silt
clay
.15
.18
.08
.07
fine

B. Sheep River section

Significance of lines

Line form	Difference probability
....	0.01 to 0.05
--------	0.06 to 0.10
— → —	0.11 to 0.20
———	0.21 to 0.30
━━━	>0.30

Figure 5-3. Transition pattern for the grain size lithologies of the Blairmore Group of the (A) type section and (B) the Sheep River section.

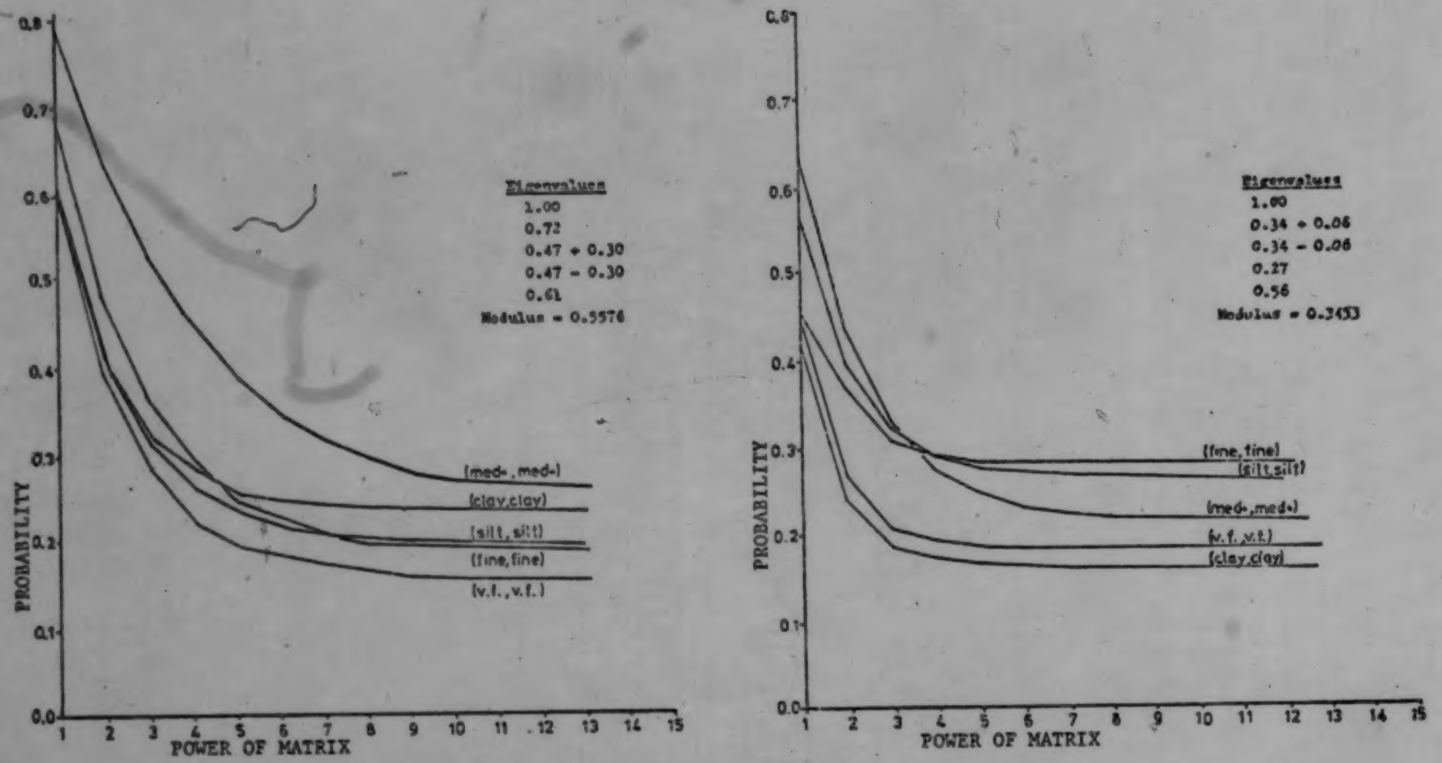


Figure 5-4. Transition probabilities of the 1 metre (left) and the 2 metre (right) sample interval matrices at successive powers of the matrices for the grain size lithologies of the complete Blairmore Group for the type section.

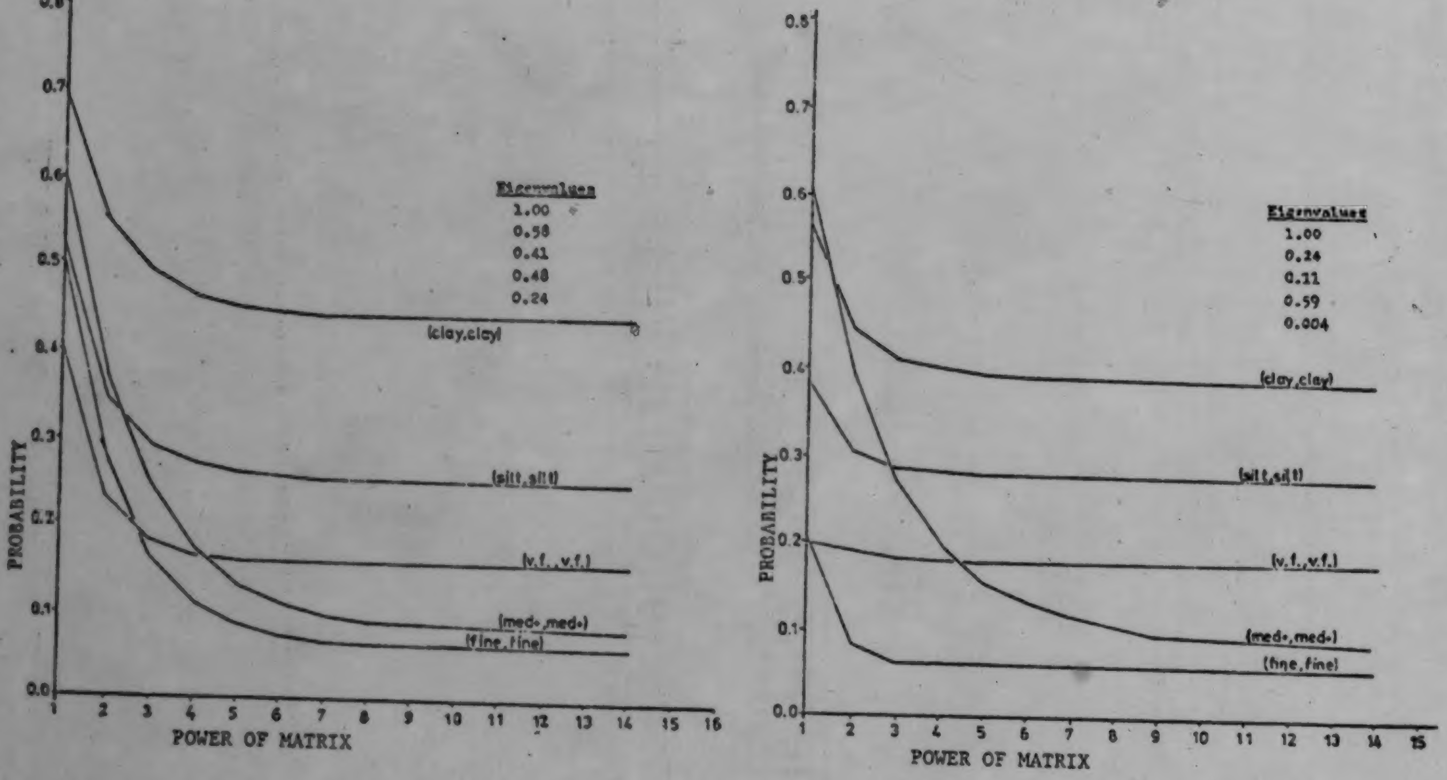


Figure 5-5. Transition probabilities of the 1 metre (left) and the 2 metre (right) sample interval matrices at successive powers of the matrices for the grain size lithologies of the complete Blairmore Group of the Sheep River section.

stable value at the 34th power. The modulus of the complex eigenvalue of this matrix was 0.5576. For the 2 metre sample interval, the matrix stabilized at the 18th power with all but one lithology reaching stability exponentially. The exception was very fine grained sandstone which decreased from 0.4483 to 0.1859 at the 7th power and then increased to 0.1861 at the 10th power. The modulus of the complex eigenvalue was 0.3453.

The type of curve described by the very fine grained sandstone mentioned in the previous paragraph was noticed in a number of instances which will be noted later. In all of the cases a complex eigenvalue was present in conjunction with variations in the fourth decimal place (single-precision computation), of the powered transition probabilities. The deviations from exponential curves were so slight that no period of recurrence was obtainable. The result was that the matrices appear non-oscillatory, although the eigenvalues showed there were strongly damped oscillations. Therefore, for the 2 metre sample interval of the Blairmore Group in the type section, the very fine grained sandstones appear to have strongly damped oscillations and no definable period of recurrence and the matrix is non-oscillatory.

The 1 and 2 metre sample matrices of the Blairmore Group in the Sheep River section reached the stable values at the 19th and 18th powers respectively. The eigenvalues in both of these matrices were all positive real numbers, and therefore, the Blairmore Group in the Sheep River section is non-oscillatory.

Lithotypes

The type section and the Sheep River section were divided into units according to the respective lithotypes described in Chapter 4. The same techniques as were used for the grain size lithology units were used to perform Markov chain analyses with lithotype units.

The null hypothesis of a random process was strongly rejected in the type section $\left[\chi^2_{\text{observed}} = 106.44 \text{ versus } \chi^2_{(.001,\ 11)} = 31.3\right]$ and in the Sheep River section $\left[\chi^2_{\text{observed}} = 156.61 \text{ versus } \chi^2_{(.001,\ 19)} = 43.8\right]$.

The difference matrix of the type section (Table 5-3) produced the transition pattern of Figure 5-6A. The matrix for the Sheep River section (Table 5-4) revealed the transition pattern of Figure 5-6B. Below each of the patterns which contain the lithotype names are the same patterns with descriptive terms substituted for the lithotype names.

The 1 metre sample interval produced from the type section stabilized at the 26th power with all of the transition probabilities decreasing exponentially (Figure 5-7). The eigenvalues are both positive real and complex numbers and the modulus is 0.4704. The oscillations indicated by the eigenvalues were strongly damped and not apparent in the actual values of the transition probabilities.

At the 2 metre interval, the matrix reached equilibrium at the 14th power and all but one of the lithotypes approached its stable value by an exponential curve. Lithotype T3 (very fine grained sandstone) reached its stable value by an oscillatory path. The eigenvalues contained both positive and negative real numbers which suggest oscillatory

Complete type section - Lithotypes

Transition probability matrix:

	T1	T2	T3	T4	T5
T1	0.00	0.39	0.22	0.27	0.12
T2	0.50	0.00	0.31	0.06	0.13
T3	0.55	0.13	0.00	0.21	0.11
T4	0.42	0.08	0.23	0.00	0.27
T5	0.29	0.24	0.24	0.24	0.00

Difference matrix:

	T1	T2	T3	T4	T5
T1	0.00	0.11	0.06	0.01	-0.06
T2	0.10	0.00	0.07	-0.15	-0.02
T3	0.14	-0.11	0.00	0.00	-0.04
T4	0.04	-0.15	0.00	0.00	0.08
T5	-0.09	0.01	0.01	0.03	0.00

$$\chi^2_{\text{observed}} = 106.448$$

$$\chi^2_{(.001,\ 11)(\text{calculated})} = 31.3$$

Table 5-3. Transition probability and difference matrices for the lithotypes of the complete Blairmore Group in the type section.

Complete Sheep River section - Lithotypes

Transition probability matrix:

	S1	S2	S3	S4	S5	S6
S1	0.00	0.31	0.24	0.13	0.11	0.20
S2	0.21	0.00	0.32	0.09	0.21	0.16
S3	0.26	0.49	0.00	0.08	0.05	0.13
S4	0.29	0.03	0.23	0.00	0.29	0.17
S5	0.37	0.14	0.09	0.23	0.00	0.17
S6	0.31	0.23	0.05	0.33	0.08	0.00

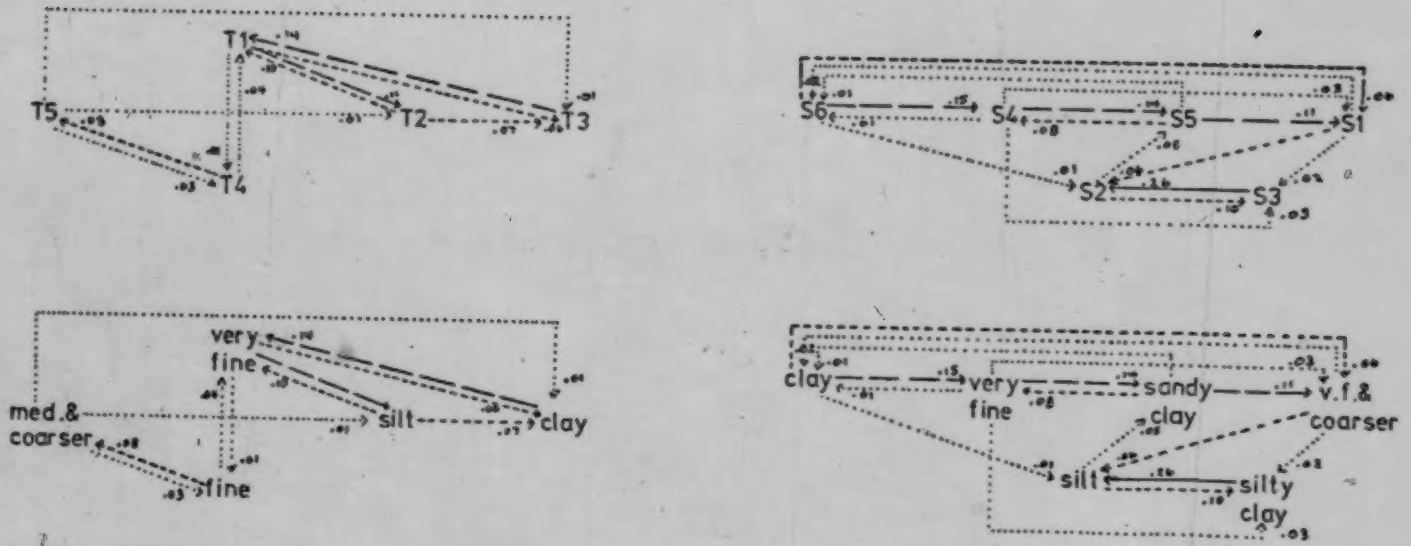
Difference matrix:

	S1	S2	S3	S4	S5	S6
S1	0.00	0.06	0.02	-0.06	-0.05	0.02
S2	-0.07	0.00	0.10	-0.08	0.05	-0.01
S3	0.00	0.26	0.00	-0.09	-0.10	-0.05
S4	0.03	-0.20	0.03	0.00	0.14	0.01
S5	0.11	-0.09	-0.11	0.08	0.00	0.01
S6	0.06	0.01	-0.15	0.15	-0.07	0.00

$$\chi^2_{\text{observed}} = 156.610$$

$$\chi^2_{(.001,\ 19)(\text{calculated})} = 43.8$$

Table 5-4. Transition probability and difference matrices for the lithotypes of the complete Blairmore Group in the Sheep River section.


T1
T2
T3
T4
T5
S1
S2
S3
S4
S5
S6
very fine
med.& coarser
fine
silt
clay
clay
very fine
sandy clay
v.f.& coarser
silt
silty clay

Significance of lines

Line form	Difference probability
··········	0.01 to 0.05
--------	0.06 to 0.10
— — —	0.11 to 0.20
———	0.21 to 0.30
▬▬▬	>0.30

Figure 5-6. Transition patterns for the lithotypes of the Blairmore Group in the type section (left) and the Sheep River section (right). Lower patterns are same as upper ones except with descriptive terms substituted for lithotype names.

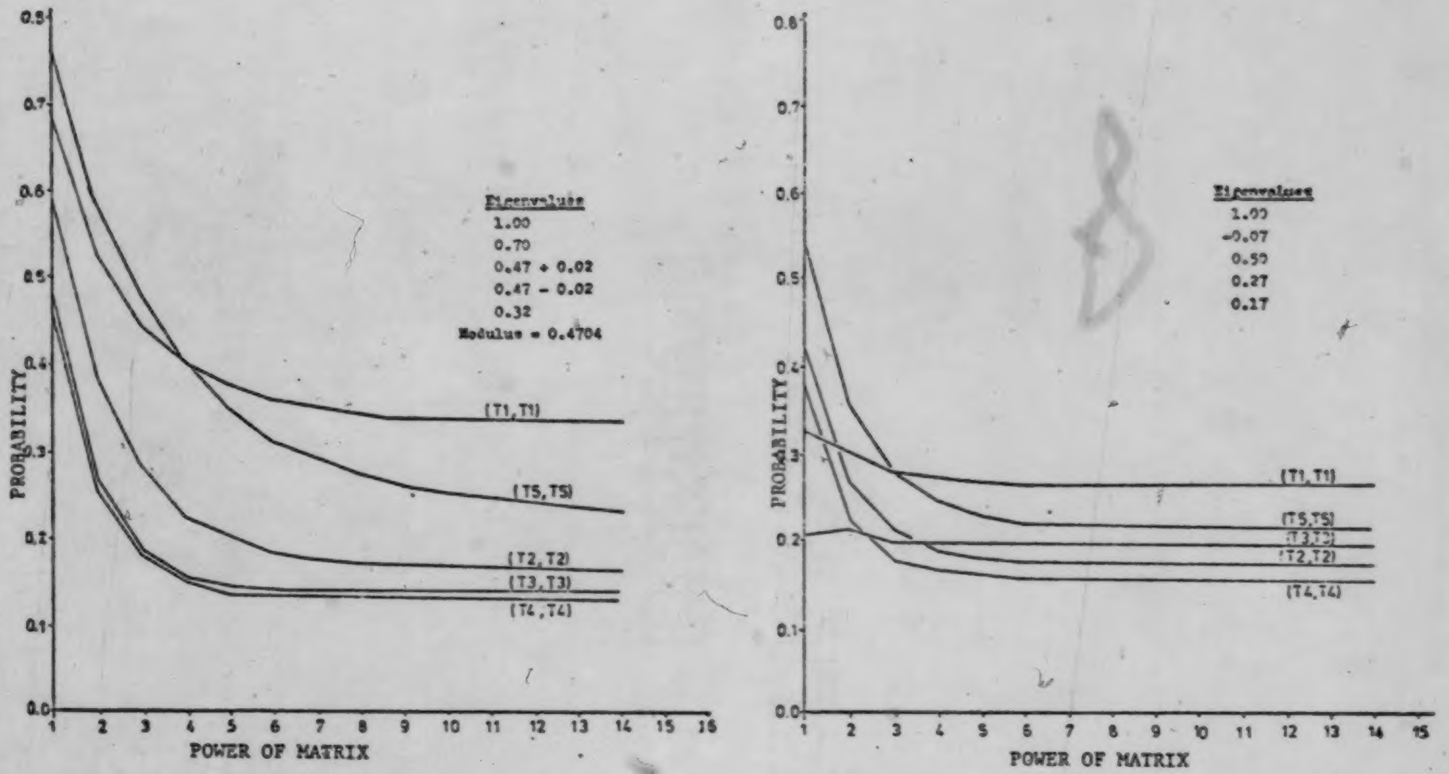


Figure 5-7. Transition probabilities of the 1 metre (left) and the 2 metre (right) sample interval matrices at successive powers of the matrices for the lithotypes of the complete Blairmore Group of the type section.

behavior. The recurrence probabilities were calculated and plotted for lithotypes T1 and T3 (Figure 5-8). Though oscillatory behavior was indicated by the eigenvalues and for T3 by the transition probabilities, no period of recurrent was found and the matrix is non-oscillatory.

The 1 metre interval matrix for the Sheep River section reached stability at the 16th power. All of the transition probabilities followed exponential curves toward the stable values (Figure 5-9) and all of the eigenvalues were positive real numbers. Therefore, the matrix represented a non-oscillating series.

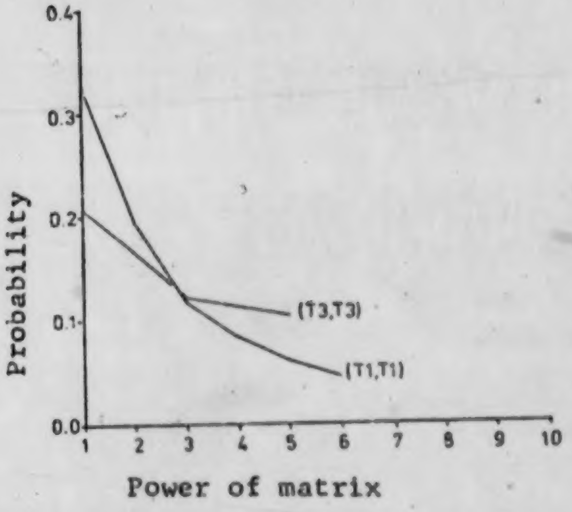


Figure 5-8. Recurrence probabilities of lithotypes T1 and T3 from the type section at the 2 metre sample interval for the complete Blairmore Group.

The transition probabilities of the 2 metre sample interval approached the constant values by exponential curves as the matrix stabilized at the 10th power (Figure 5-9). A complex number with a modulus of 0.1030 was contained in the eigenvalues and small fluctuations were noted in two of the lithotypes. Lithotype S3 (silty claystone) decreased from 0.2550 to 0.1084 at the 8th power and then increased to

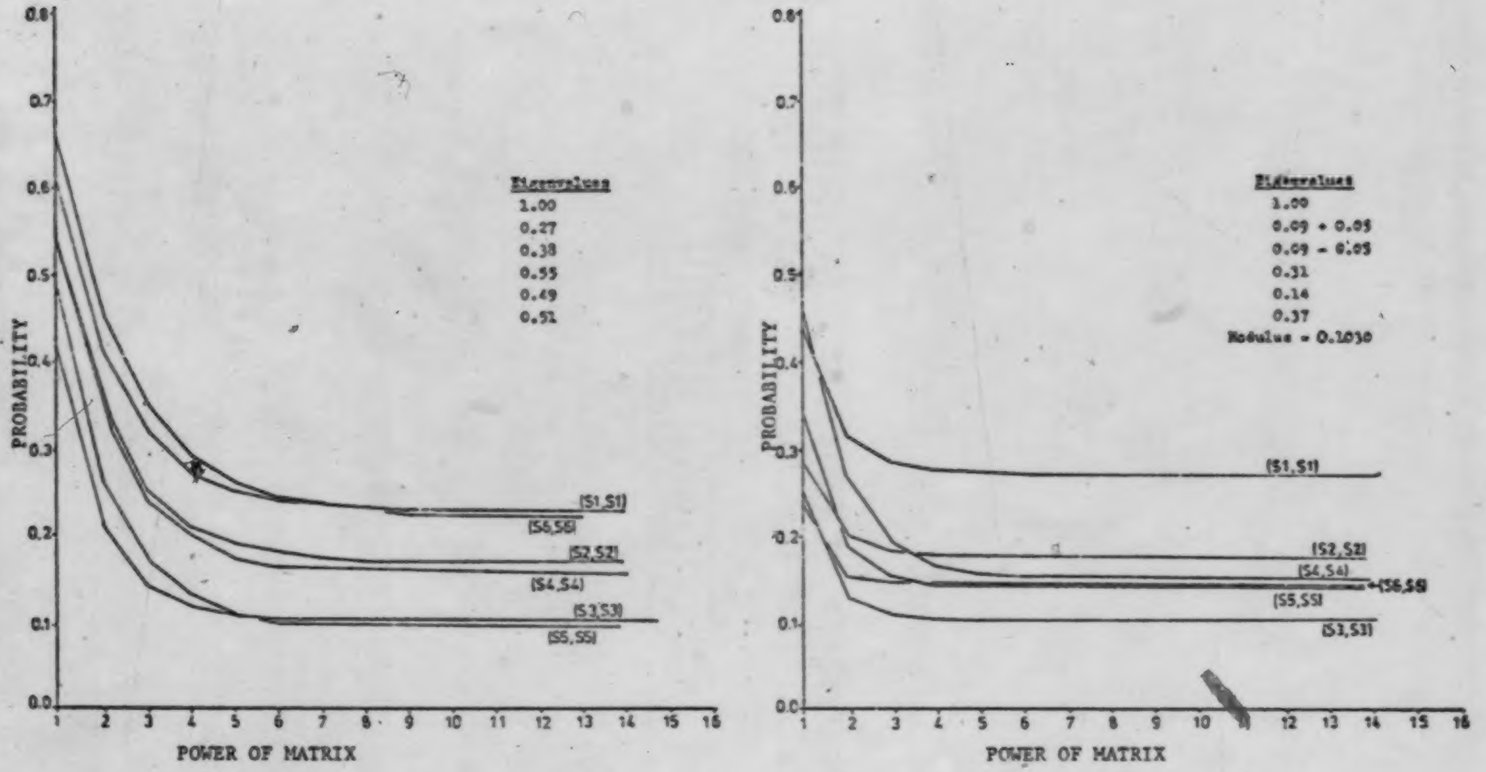


Figure 5-9. Transition probabilities of the 1 metre (left) and 2 metre (right) sample interval matrices at successive powers of the matrices for the lithotypes of the complete Blairmore Group in the Sheep River section.

0.1085. Lithotype S6 (claystone) decreased from 0.2381 to 0.1480 at the 4th power and increased to 0.1483 at the 18th power. The oscillatory behavior of these lithotypes was extremely damped with no period of recurrence and the matrix proved to be non-oscillatory.

5.3 Results for the Beaver Mines Formation

The Beaver Mines Formation was separated from the rest of the Blairmore Group for the Markov and geological cyclicity analyses because it forms the bulk of the group, was present in all of the sections, and was the best exposed of the three formations. Again only the embedded Markov model was used to test for Markovian dependency since the thicknesses of the lithologic units, especially the coarser grained units, have non-geometric distributions. See Figures 5-10, 5-11, and 5-12. The regular chain structure was used to test for geological cyclicity.

Grain size lithologies

Using grain size to define lithologic units, the observed chi-square value for the Beaver Mines Formation in the type section was 98.550, in the Sheep River section 96.935, and in the Burnt Timber Creek section 124.497. When compared to the calculated χ^2 value of 31.3 (11 degrees of freedom), it can be seen that the null hypothesis was rejected at a 99.9% level of confidence in all instances.

The transition probability and difference matrices for the Beaver Mines Formation in the type section (Table 5-5), the Sheep River section (Table 5-6), and the Burnt Timber Creek section (Table 5-7) produced the transition patterns found in Figure 5-13.

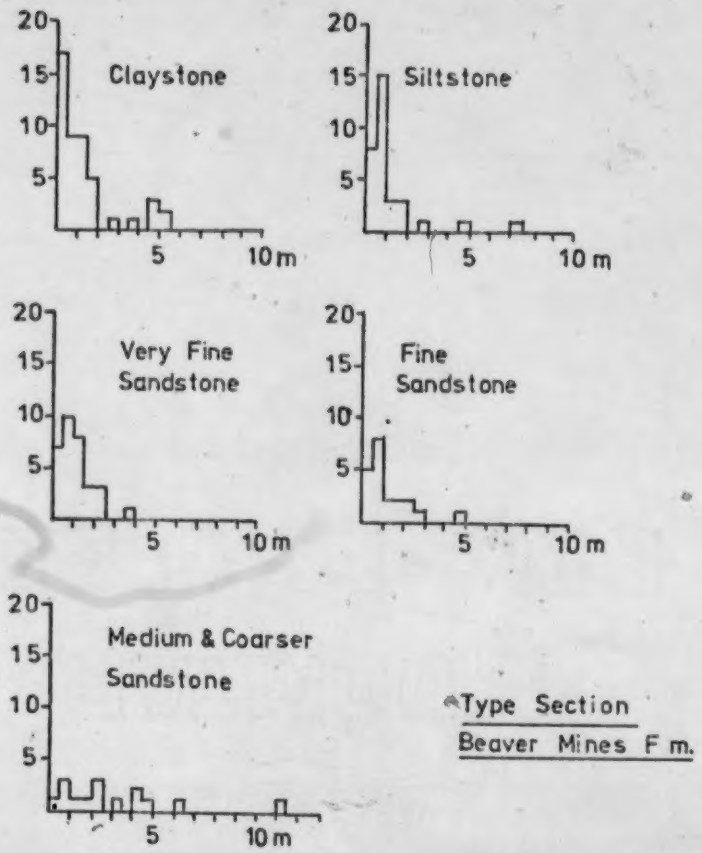


Figure 5-10. Frequency distributions of the lithologic unit thicknesses of the Beaver Mines Formation in the type section. The vertical axes are in terms of the number of lithologic units.

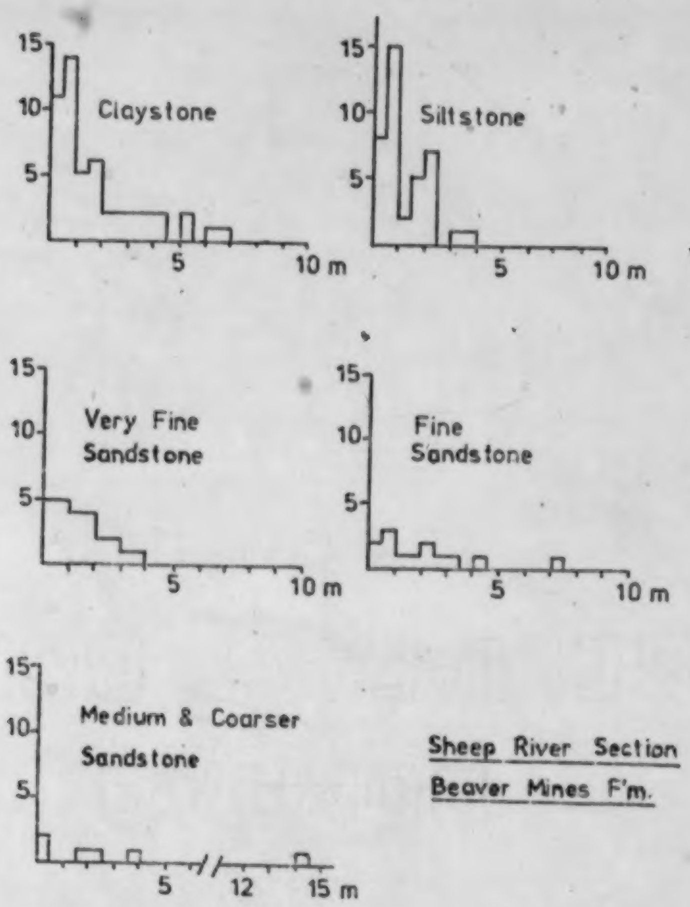


Figure 5-11. Frequency distributuions of lithologic unit thicknesses of the Beaver Mines Formation in the Sheep River section. The vertical axes are in terms of the number of units.

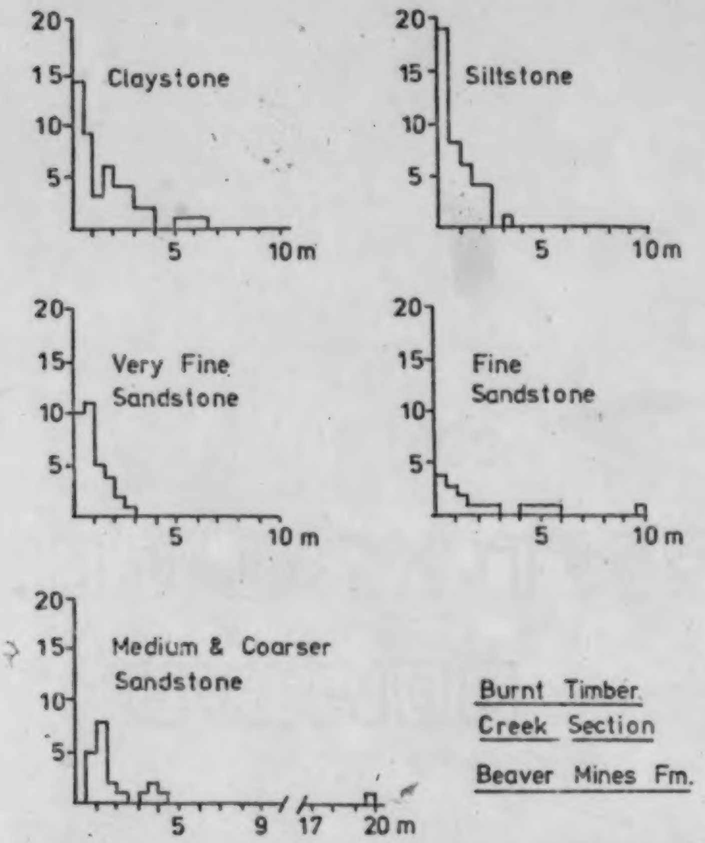


Figure 5-12. Frequency distributions of lithologic unit thicknesses of the Beaver Mines Formation in the Burnt Timber Creek section. Vertical axes are in terms of the number of units.

Type section - Beaver Mines Formation - Grain size lithologies

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.51	0.16	0.23	0.09
silt	0.48	0.00	0.33	0.07	0.11
v.f.	0.50	0.27	0.00	0.12	0.12
fine	0.53	0.00	0.29	0.00	0.18
med+	0.38	0.00	0.31	0.31	0.00

Difference matrix:

	clay	silt	[illegible]	fine	med+
clay	0.00	0.18	-0.15	0.02	-0.06
silt	0.08	0.00	[illegible]	[illegible]	0.02
v.f.	0.10	-0.01	0.00	[illegible]	-0.01
fine	0.24	-0.27	0.06	0.00	0.06
med+	0.03	-0.26	0.09	0.14	0.00

$\chi^2_{\text{observed}} = 98.55$

$\chi^2_{(.001,\ 11)(\text{claculated})} = 31.3$

Table 5-5. Transition probability and difference matrices for the grain size lithologies of the Beaver Mines Formation in the type section.

Sheep River section - Beaver Mines Formation - Grain size lithologies

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.51	0.29	0.13	0.07
silt	0.76	0.00	0.16	0.05	0.03
v.f.	0.48	0.38	0.00	0.05	0.10
fine	0.45	0.18	0.18	0.00	0.18
med+	0.29	0.43	0.00	0.29	0.00

Difference matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.04	0.01	0.01	-0.04
silt	0.22	0.00	-0.09	-0.07	-0.06
v.f.	0.03	0.02	0.00	-0.06	0.02
fine	0.05	-0.17	0.00	0.00	0.11
med+	-0.10	0.10	-0.18	0.19	0.00

$$\chi^2_{\text{observed}} = 96.935$$

$$\chi^2_{(.001,\ 11)(\text{calculated})} = 31.3$$

Table 5-6. Transition probability and difference matrices for the grain size lithologies of the Beaver Mines Formation in the Sheep River section.

Burnt Timber Creek section - Beaver Mines Formation -
Grain size lithologies

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.38	0.36	0.13	0.13
silt	0.69	0.00	0.19	0.08	0.03
v.f.	0.36	0.46	0.00	0.00	0.18
fine	0.13	0.20	0.27	0.00	0.40
med+	0.06	0.11	0.33	0.50	0.00

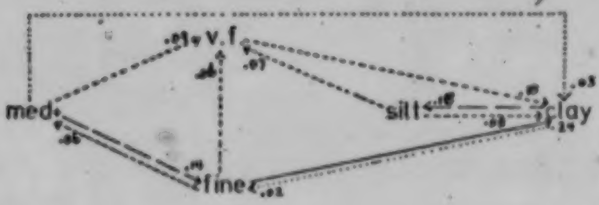
Difference matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.04	0.05	-0.04	-0.04
silt	0.32	0.00	-0.19	-0.08	-0.13
v.f.	0.00	0.14	0.00	-0.17	0.01
fine	-0.19	-0.07	0.01	0.00	0.25
med+	-0.26	-0.17	0.07	0.36	0.00

$$\chi^2_{\text{observed}} = 124.497$$

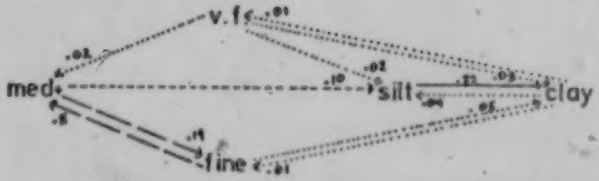
$$\chi^2_{(.001,\ 11)} = 31.3$$

Table 5-7. Transition probability and difference matrices for the grain size lithologies of the Beaver Mines Formation in the Burnt Timber Creek section.



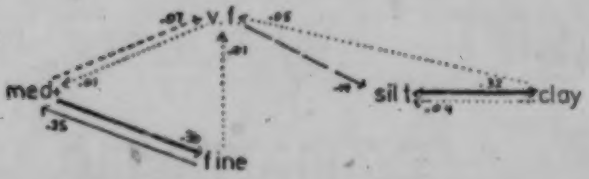
.01
v.f
.07
med
.06
silt
clay
.03
fine
.01

A. Type section



v.f
.01
.02
med
.10
.02
silt
.03
clay
.04
.05
fine
.01

B. Sheep River section



.02
v.f
.05
.01
med
.01
silt
.32
clay
.04
.35
fine

C. Burnt Timber Creek section

Significance of lines

Line form	Difference probability
············	0.01 to 0.05
--------	0.06 to 0.10
— — —	0.11 to 0.20
———	0.21 to 0.30
━━━	>0.30

Figure 5-13. Transition pattern of the grain size lithologies of the Beaver Mines Formation in the (A) type section, (B) the Sheep River section, and (C) the Burnt Timber Creek section.

The transition probabilities of the Beaver Mines in the type section at the 1 metre interval followed exponential curves while approaching the stable value at the 31st power. The eigenvalues were both positive real and complex numbers with a modulus of 0.3704. Transition probabilities of the fine grained sandstones deviated from its exponential curve by decreasing from 0.4167 to 0.1322 at the 7th power and increasing to 0.1337 at the 18th power. This matrix is non-oscillating even considering the strongly damped oscillations of the fine grained sandstones which had no period of recurrence.

The 2 metre sample interval matrix stabilized at the 22nd power with the lithologies of claystone and very fine grained sandstone describing oscillating curves and the rest exponential curves (Figure 5-14). The eigenvalues contained one negative real number while the remainder were positive real numbers. The recurrence probabilities of the oscillating lithologies were calculated and plotted (Figure 5-15). A period of recurrence of 4 metres was found for the very fine grained sandstones and no period of recurrence was found for the claystones. Therefore, the very fine grained sandstones are oscillatory with a recurrence of 4 metres, the oscillations of the claystones are strongly damped, and the rest of the Beaver Mines Formation in the type section is non-oscillatory.

In the Sheep River section, the 1 metre interval matrix of the Beaver Mines Formation stabilized at the 27th power. All of the transition probabilities described exponential curves upon powering (Figure 5-16) and all of the eigenvalues were positive real numbers. The matrix is non-oscillatory.

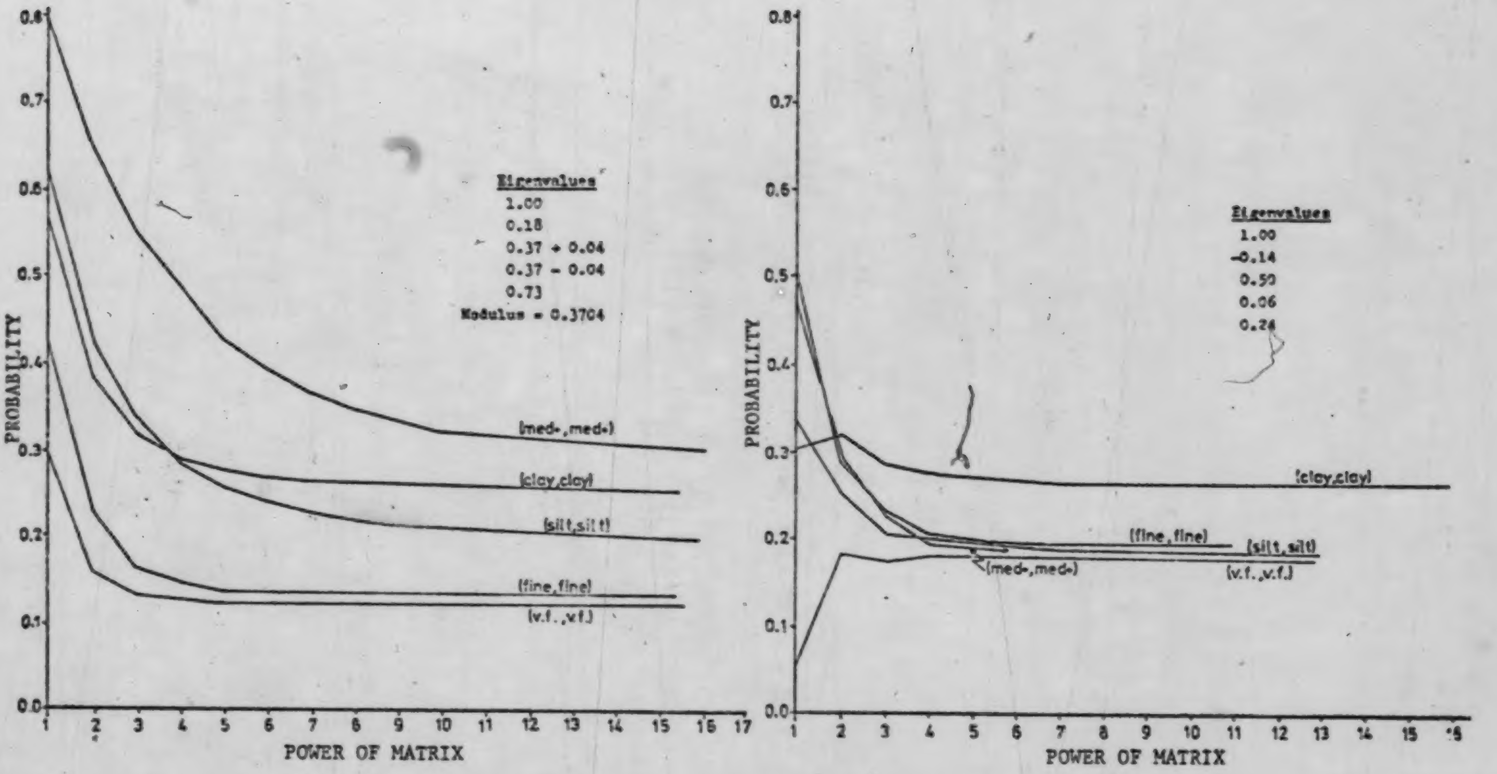


Figure 5-14. Transition probabilities of the 1 metre (left) and 2 metre (right) sample interval matrices at the successive powers of the matrices for the grain size lithologies of the Beaver Mines Formation in the type section.

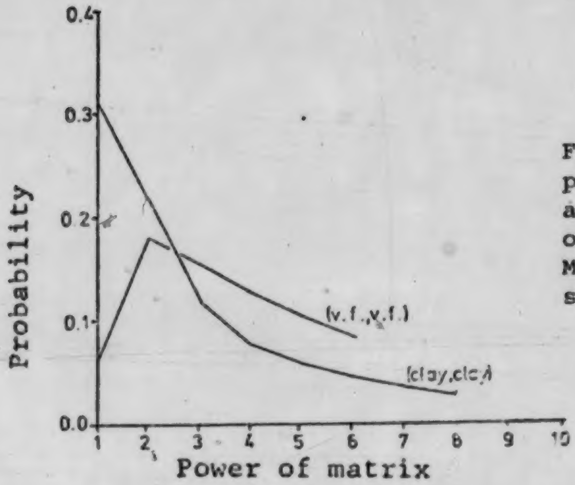


Figure 5-15. Recurrence probabilities of claystone and very fine grained sandstone of the type section, Beaver Mines Formation at the 2 metre sample interval.

At the 2 metre interval, the plot of the transition probabilities showed all of the probabilities following exponential curves as the matrix approached its stable value at the 40th power. The eigenvalues contained positive real numbers as well as complex numbers with a modulus of 0.7003. Upon close examination, it was clear that two lithologies deviated slightly from the exponential curves. The siltstone probabilities decreased from 0.2609 to 0.2236 at the 6th power and increased to 0.2249 by the 14th power. The probabilities of fine grained sandstone decreased from 0.4444 to 0.0716 at the 11th power and had increased to 0.0718 by the 16th power. The oscillations were strongly damped and had no period of recurrence and therefore, the matrix was non-oscillatory.

The Beaver Mines Formation in the Burnt Timber Creek section was sampled at 1 metre intervals and was found to be non-oscillatory. The matrix reached stability at the 30th power; all of the transition probabilities decreased exponentially (Figure 5-17) and all of the eigenvalues were positive real numbers.

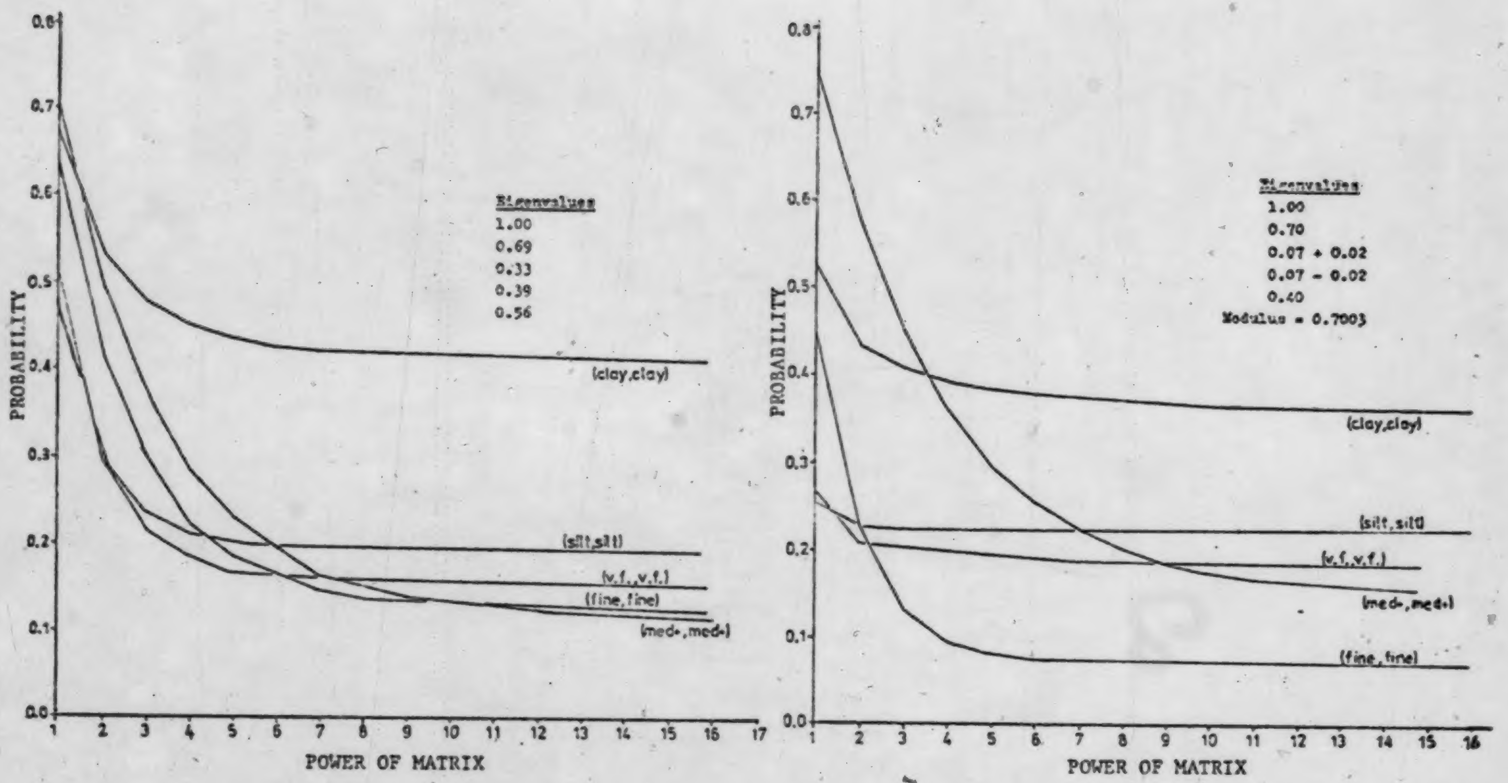


Figure 5-16. Transition probabilities of the 1 metre (left) and 2 metre (right) sample interval matrices at successive powers of the matrices for the grain size lithologies of the Beaver Mines Formation in the Sheep River section.

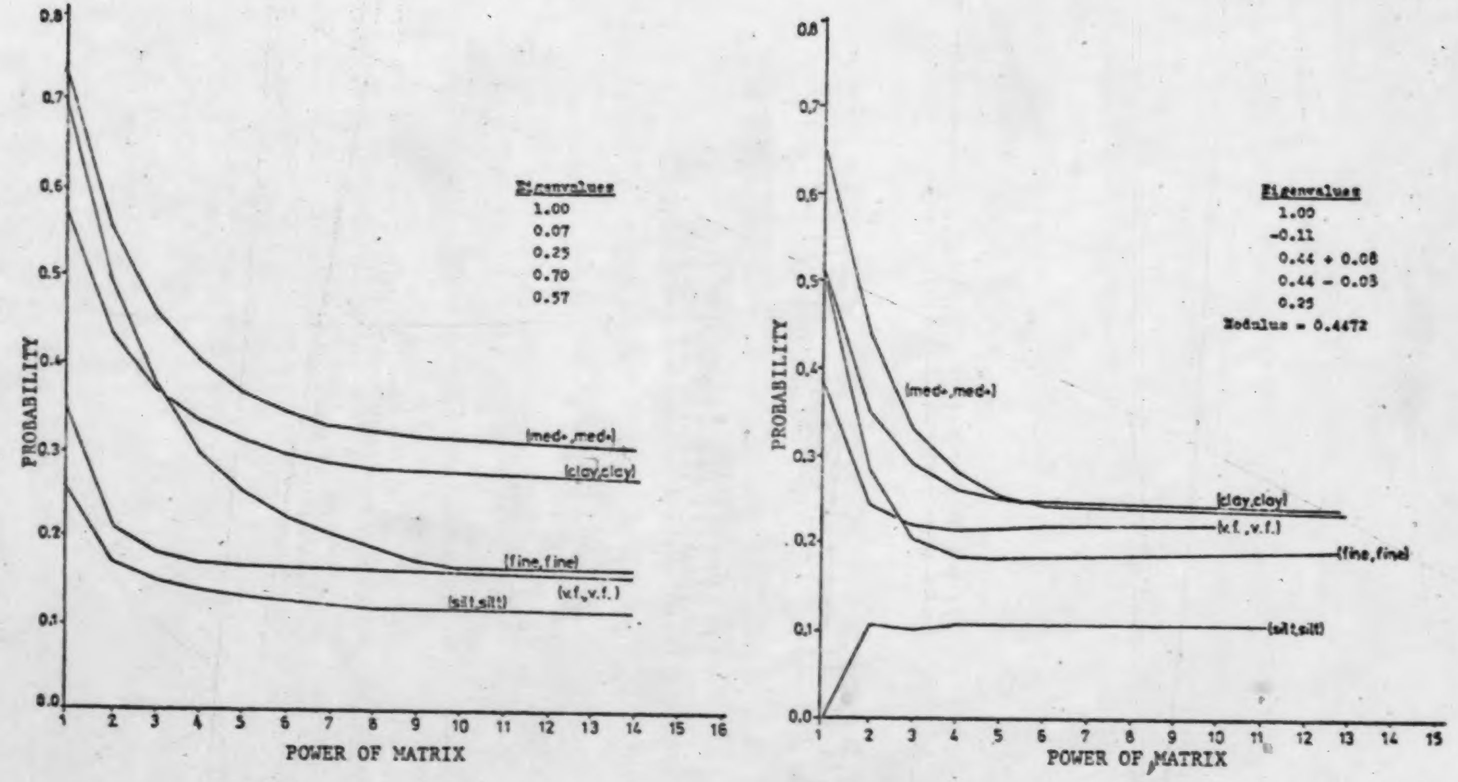


Figure 5-17. Transition probabilities of the 1 metre (left) and 2 metre (right) sample interval matrices at successive powers of the matrices for the grain size lithologies of the Beaver Mines Formation in the Burnt Timber Creek section.

At 2 metre intervals, the matrix reached its stable value at the 45th power. The graph of the transition probabilities (Figure 5-17) showed the lithology of siltstone followed an oscillating path whereas the other probabilities decreased exponentially. The eigenvalues were both positive and negative real numbers as well as complex numbers; the modulus of the complex number was 0.4472. The recurrence probabilities of the siltstone lithology were plotted (Figure 5-18) showing a period of recurrence of 4 metres. The lithologies of very fine grained sandstone and fine sandstone exhibited small deviations from their exponential curves. The probabilities of the very fine grained sandstones decreased from 0.3750 to 0.2202 by the 6th power and then increased to 0.2214 at the 10th power. The fine grained sandstone probabilities decreased from 0.5000 to 0.1833 at the 5th power and then increased to 0.1913 at the 13th power. Therefore, in the Burnt Timber Creek section at the 2 metre sample interval the Beaver Mines Formation lithologies

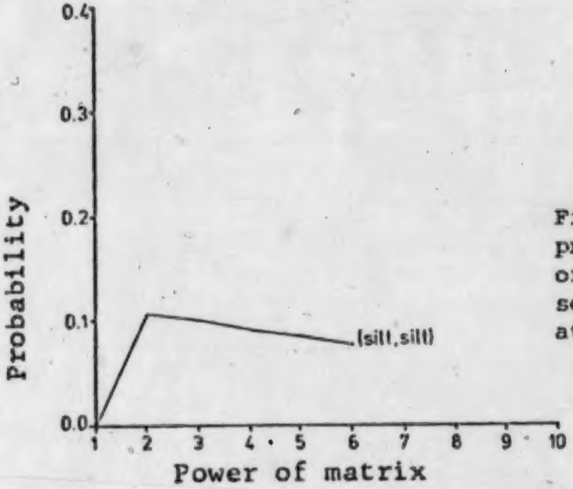


Figure 5-18. Recurrence probabilities of siltstone of the Burnt Timber Creek section Beaver Mines Formation at the 2 metre sample interval.

of claystone and medium to coarser grained sandstone are non-oscillatory, the fine and very fine grained sandstones had strongly damped oscillations with no period of recurrence, and the siltstones were oscillatory with a period of recurrence of 4 metres.

Lithotypes

The lithotypes described in Chapter 4 for the Beaver Mines Formation samples were used to code that formation in each of the measured sections. The same analyses as previously discussed were conducted on the formation using these lithotypes.

In the type section, the observed test statistic for the Beaver Mines Formation, 89.761, justified the rejection of the null hypothesis at a 99.9% level of confidence when compared to the χ^2 value of 43.8 (19 degrees of freedom).

The difference matrix (Table 5-8) produced the transition pattern of Figure 5-19 for the Beaver Mines lithotypes of the type section. Again, the pattern is presented with both the lithotype names and descriptive terms. This is done for the remaining patterns also.

The 1 metre interval matrix of the Beaver Mines Formation in the type section, upon powering, all decreased exponentially (Figure 5-20). The eigenvalues contained complex numbers with a modulus of 0.3314. No deviations from the exponential curves were noted in any of the probabilities and therefore, the matrix is non-oscillatory.

At the 2 metre interval, the matrix reached its stable condition at the 15th power. Lithotype TBM2 followed an oscillatory path whereas the rest of the lithotype probabilities traced exponential curves (Figure 5-20). The eigenvalues were positive real and negative real

Type section - Beaver Mines Formation - Lithotypes

Transition probability matrix:

	TBM1	TBM2	TBM3	TBM4	TBM5	TBM6
TBM1	0.00	0.32	0.11	0.14	0.14	0.29
TBM2	0.13	0.00	0.25	0.08	0.29	0.25
TBM3	0.00	0.29	0.00	0.29	0.07	0.36
TBM4	0.19	0.31	0.13	0.00	0.06	0.31
TBM5	0.36	0.21	0.29	0.07	0.00	0.07
TBM6	0.55	0.17	0.14	0.14	0.00	0.00

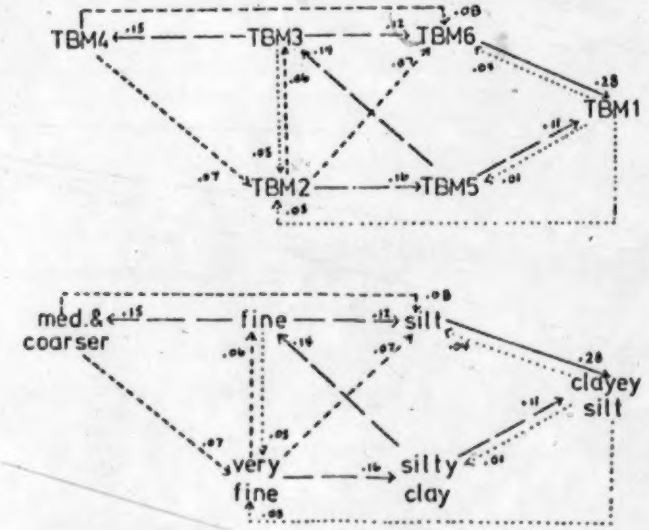
Difference matrix:

	TBM1	TBM2	TBM3	TBM4	TBM5	TBM6
TBM1	0.00	0.05	-0.09	-0.01	0.01	0.04
TBM2	-0.14	0.00	0.06	-0.07	0.16	-0.01
TBM3	-0.25	0.05	0.00	0.15	-0.05	0.12
TBM4	-0.06	0.07	-0.04	0.00	-0.06	0.08
TBM5	0.11	-0.03	0.14	-0.07	0.00	-0.16
TBM6	0.28	-0.09	-0.05	-0.01	-0.13	0.00

$$\chi^2_{\text{observed}} = 89.761$$

$$\chi^2_{(.001,\ 19)(\text{calculated})} = 43.8$$

Table 5-8. Transition probability and difference matrices for the lithotypes of the Beaver Mines Formation in the type section.


TBM4
TBM3
TBM6
TBM1
TBM2
TBM5
.15
.11
.08
.19
.07
.04
.28
.06
.05
.16
med.&
coarser
fine
silt
clayey
silt
very
fine
silty
clay

Significance of lines

Line form	Difference probability
··············	0.01 to 0.05
--------	0.06 to 0.10
— — —	0.11 to 0.20
———	0.21 to 0.30
━━━	> 0.30

Figure 5-19. Transition pattern for the lithotypes of the Beaver Mines Formation of the type section. The lower pattern is the same as the upper one except with descriptive terms substituted for the lithotype names.

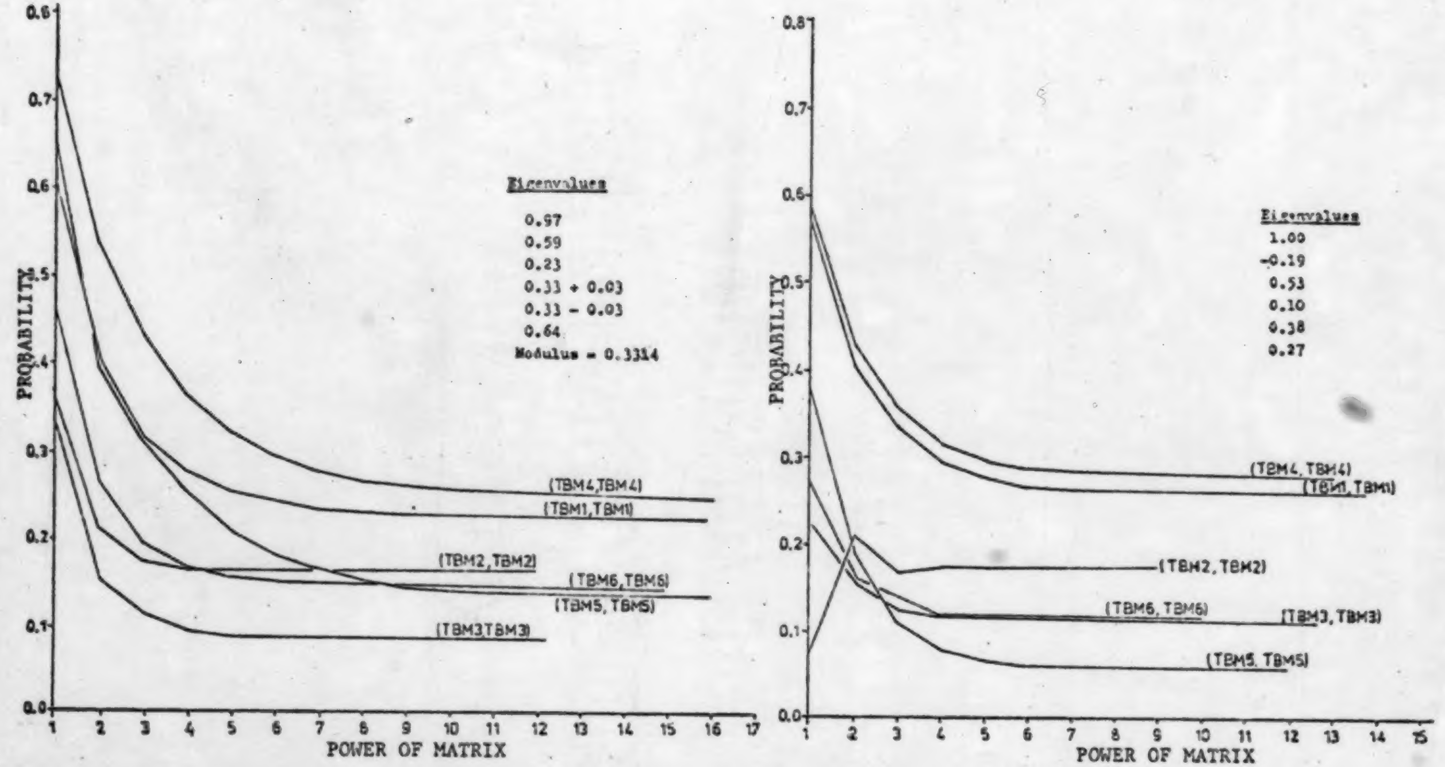


Figure 5-20. Transition probabilities of the 1 metre (left) and 2 metre (right) sample interval matrices at successive powers of the matrices for the lithotypes of the Beaver Mines Formation in the type section.

numbers. The matrix is non-oscillatory except for lithotype TBM2 (very fine grained sandstone) which had a period of recurrence of 4 metres (Figure 5-21).

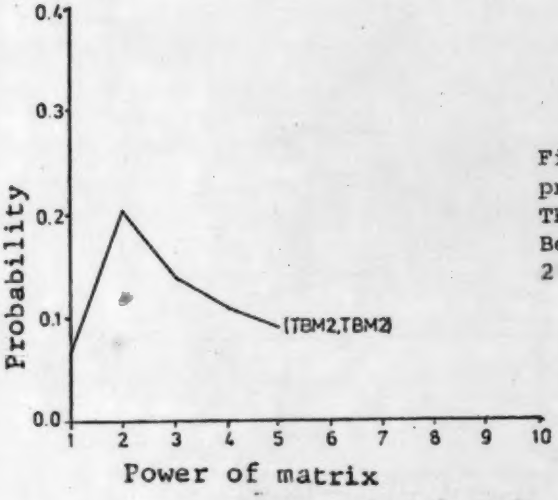


Figure 5-21. Recurrence probabilities of lithotype TBM2 of the type section Beaver Mines Formation at the 2 metre sample interval.

The null hypothesis of a random process was rejected for the Beaver Mines Formation in the Sheep River section at a 99.9% level of confidence as can be seen by comparing the observed test statistic of 94.914 with the χ^2 value of 58.3 with 29 degrees of freedom.

The difference matrix for the Beaver Mines in the Sheep River section (Table 5-9) produced the transition pattern of Figure 5-22.

At the 1 metre sample interval, the matrix of transition probabilities stabilized to the fourth decimal place at the 38th power. The probabilities decreased exponentially (Figure 5-23) and the eigenvalues contained complex numbers with the modulus of 0.3523. No deviations from the exponential curves were observable but after the matrix had been raised to the 50th power it had not stabilized at the fifth decimal place and fluctuations at this level may have accounted

Sheep River section - Beaver Mines Formation - Lithotypes

Transition probability matrix:

	SBM1	SBM2	SBM3	SBM4	SBM5	SBM6	SBM7
SBM1	0.00	0.00	0.05	0.16	0.21	0.21	0.37
SBM2	0.00	0.00	0.11	0.33	0.22	0.11	0.22
SBM3	0.00	0.00	0.11	0.33	0.22	0.11	0.22
SBM4	0.20	0.00	0.07	0.00	0.13	0.13	0.47
SBM5	0.14	0.11	0.04	0.11	0.00	0.29	0.32
SBM6	0.32	0.05	0.05	0.05	0.47	0.00	0.05
SBM7	0.12	0.20	0.00	0.28	0.32	0.08	0.00

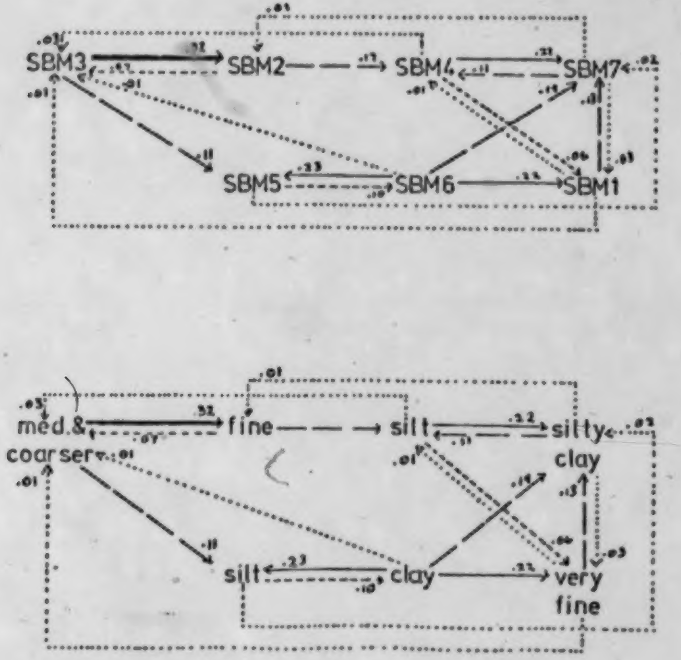
Difference matrix:

	SBM1	SBM2	SBM3	SBM4	SBM5	SBM6	SBM7
SBM1	0.00	-0.19	0.01	0.01	-0.03	-0.06	0.13
SBM2	-0.14	0.00	0.07	0.17	-0.03	-0.05	-0.03
SBM3	-0.13	0.32	0.00	-0.14	0.11	-0.14	-0.05
SBM4	0.06	-0.19	0.03	0.00	-0.12	-0.02	0.22
SBM5	-0.04	-0.13	-0.02	-0.08	0.00	0.10	0.02
SBM6	0.22	-0.14	0.01	-0.11	0.23	0.00	0.19
SBM7	0.03	0.01	-0.04	0.11	-0.04	-0.09	0.00

$$\chi^2_{\text{observed}} = 94.914$$

$$\chi^2_{(.001,\ 29)(\text{ calculated})} = 58.3$$

Table 5-9. Transition probability and difference matrices for the lithotypes of the Beaver Mines Formation of the Sheep River section.


SBM3
SBM2
SBM4
SBM7
SBM5
SBM6
SBM1
.01
.32
.21
.11
.23
.10
.22
.01
med.&
coarser
fine
silt
silty
clay
silt
clay
very
fine
.01
.32
.22
.23
.10
.22

Significance of lines

Line form	Difference probability
··············	0.01 to 0.05
--------	0.06 to 0.10
— — —	0.11 to 0.20
———	0.21 to 0.30
━━━	>0.30

Figure 5-22. Transition pattern for the lithotypes of the Beaver Mines Formation in the Sheep River section. The lower pattern is the same as the upper one except descriptive terms have been substituted for the lithotype names.

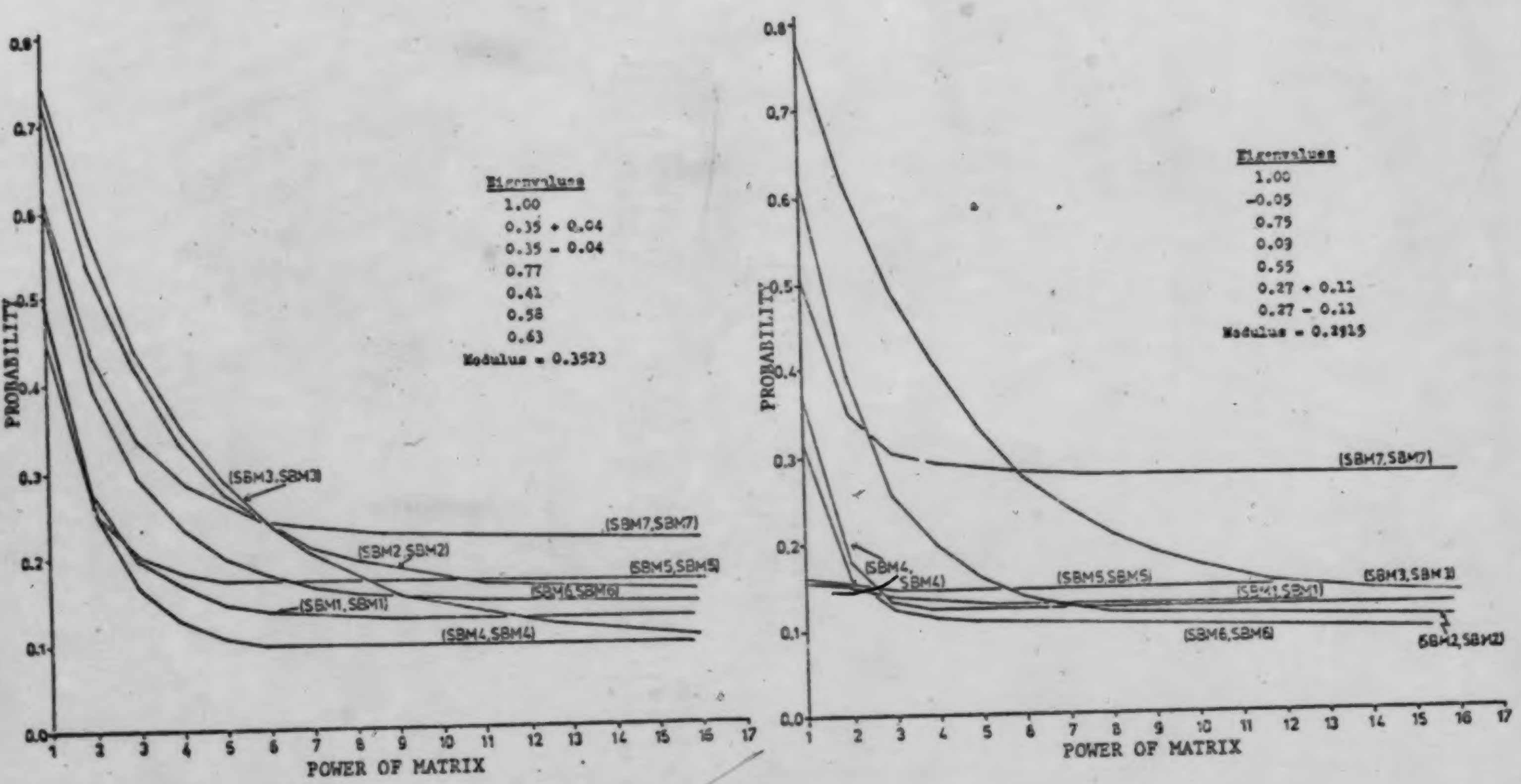


Figure 5-23. Transition probabilities of the 1 metre (left) and 2 metre (right) sample interval matrices at successive powers of the matrices for the lithotypes of the Beaver Mines Formation in the Sheep River section.

for the damped oscillations suggested by the eigenvalues. Overall, the matrix is non-oscillatory.

At the 2 metre interval, the transition probabilities appear to have decreased exponentially, except for SBM1 and SBM2, toward stability at the 38th power. The two exceptions followed nearly horizontal lines. Since a horizontal line would represent a random process and SBM1 and SBM2 nearly follow that type of path they are obviously non-oscillatory. The eigenvalues contained negative real and complex numbers, both suggesting oscillating behavior. A modulus of 0.2915 suggested any oscillations were strongly damped and the lithotypes SBM4 and SBM5 (both clayey sandstone) were found to have slight fluctuations from exponential curves. The transition probabilities of SBM4 decreased from 0.3636 to 0.1242 at the 8th power and then increased to 0.1247 at the 17th power. The probabilities of SBM5 decreased from 0.1579 to 0.1469 at the 6th power, increased to 0.1470 by the 10th power, and then decreased to 0.1468 at the 15th power. The matrix is non-oscillatory including the lithotypes SBM4 and SBM5, the oscillations of which were strongly damped and had no period of recurrence.

For the Beaver Mines Formation in the Burnt Timber Creek section, comparison of the observed test statistic value of 87.257 with the χ^2 value of 31.3 (99.9% level of conficence, 11 degrees of freedom) caused the rejection of the null hypothesis of a random process.

The difference matrix for the Beaver Mines Formation in the Burnt Timber Creek section (Table 5-10) revealed the transition pattern of Figure 5-24.

Structured at the 1 metre sample interval, the probabilities of the lithotypes of the Beaver Mines all decreased exponentially as the

Burnt Timber Creek section - Beaver Mines Formation - Lithotypes

Transition probability matrix:

	B1	B2	B3	B4	B5
B1	0.00	0.33	0.44	0.11	0.11
B2	0.20	0.00	0.40	0.13	0.27
B3	0.09	0.06	0.00	0.50	0.35
B4	0.00	0.11	0.32	0.00	0.57
B5	0.13	0.16	0.41	0.31	0.00

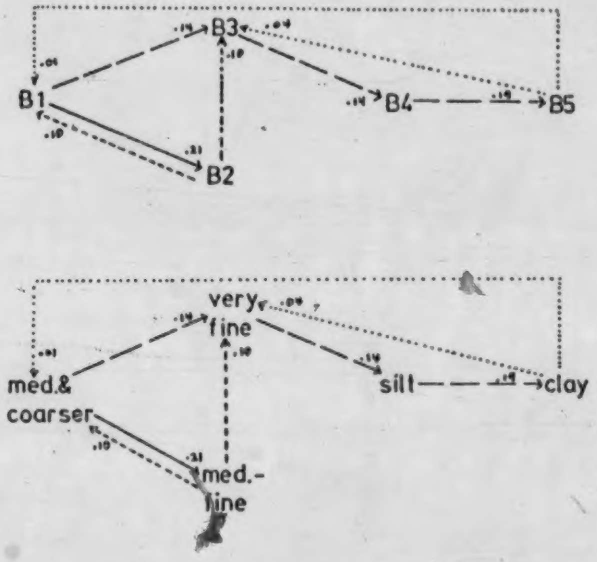
Difference matrix:

	B1	B2	B3	B4	B5
B1	0.00	0.21	0.14	-0.17	-0.19
B2	0.10	0.00	0.10	-0.16	-0.04
B3	-0.02	-0.09	0.00	0.14	-0.03
B4	-0.11	-0.03	-0.05	0.00	0.19
B5	0.01	0.00	0.04	-0.04	0.00

$$\chi^2_{\text{observed}} = 87.257$$

$$\chi^2_{(.001,11)(\text{calculated})} = 31.3$$

Table 5-10. Transition probability and difference matrices of the lithotypes of the Beaver Mines Formation in the Burnt Timber Creek section.


B1
B2
B3
B4
B5
.14
.04
.01
.10
.10
.21
.14
.14
very fine
med.& coarser
med.-fine
silt
clay

Significance of lines

Line form	Difference probability
············	0.01 to 0.05
--------	0.06 to 0.10
— — —	0.11 to 0.20
———	0.21 to 0.30
━━━	>0.30

Figure 5-24. Transition pattern for the lithotypes of the Beaver Mines Formation in the Burnt Timber Creek section. The lower pattern is the same as the upper one except with descriptive terms substituted for the lithotype names.

matrix approached its stable value to the fourth decimal place at the 45th power (Figure 5-25). After the 50th power stability had not been achieved at the fifth decimal place which explains the occurrence of complex numbers in the eigenvalues. The modulus of 0.4428 indicates strong damping of any oscillations and the matrix is non-oscillatory.

At the 2 metre sample interval, lithotype B4 (siltstone) traced an oscillatory path, whereas the other lithotypes decreased exponentially as the matrix approached its stable value at the 35th power (Figure 5-25). The eigenvalues contained both positive and negative real numbers. The lithotype B4 was found to be oscillatory with a period of recurrence of 4 metres (Figure 5-26) and the rest of the lithotypes were non-oscillatory.

5.4 Summary

The results of the Markov analyses of the Blairmore Group are summarized in Table 5-11. For the Beaver Mines Formation the summarized results are in Table 5-12.

In all instances examined, the complete Blairmore Group and the Beaver Mines Formation proved to have been controlled by a first-order Markov process or, in other words, to have Markovian memory extending back one event. The null hypothesis of a random process having been responsible for the vertical arrangement of the measured sections was strongly rejected in all cases.

All of the transition patterns exhibited some variation of a fining-upward sequence of lithologies. Many of the examples did not contain a prominent transition back to the coarser grained units at the completion of the fining-upward pattern. Notably, a number of these

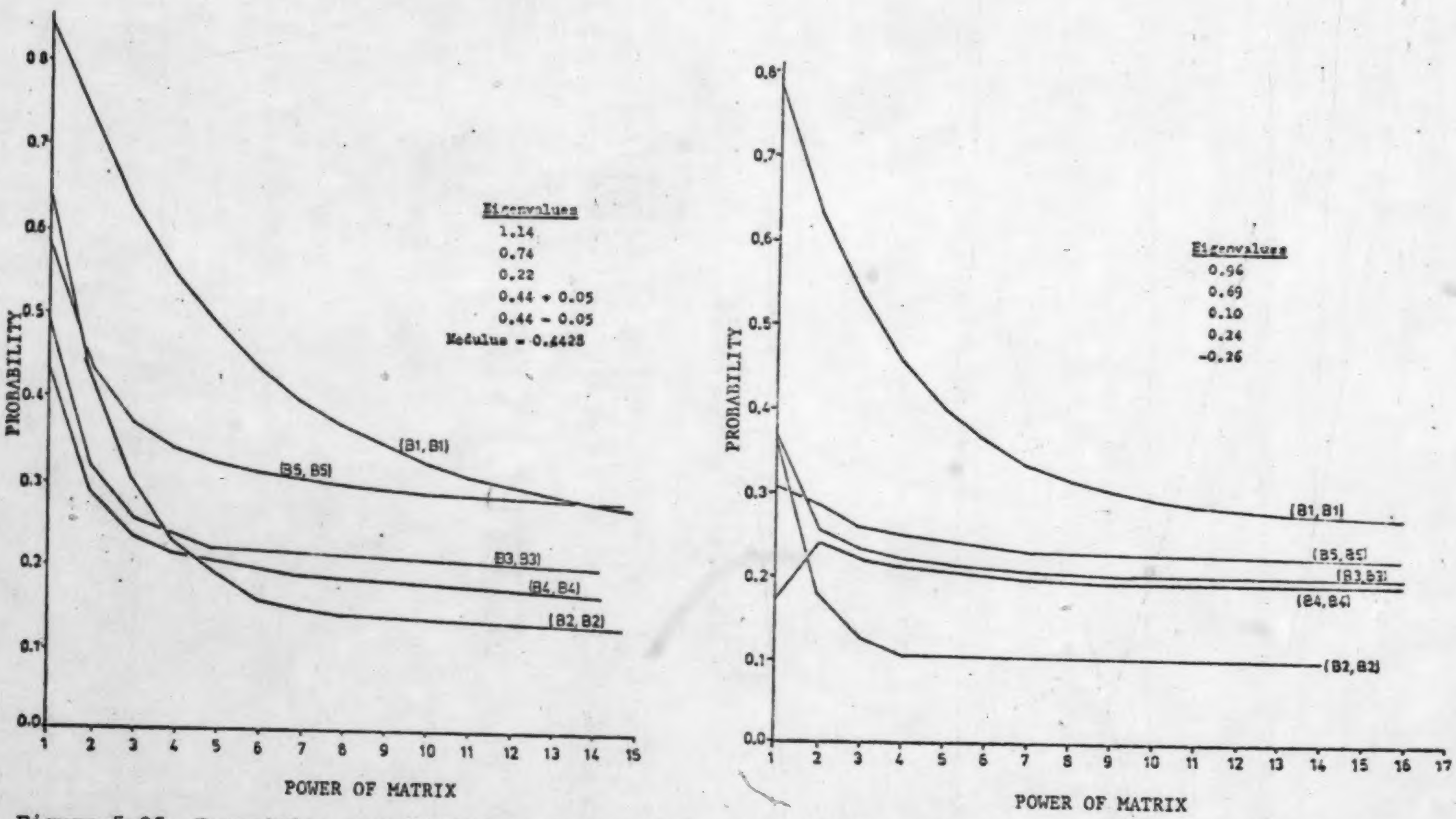


Figure 5-25. Transition probabilities of the 1 metre (left) and 2 metre (right) sample interval matrices for the lithotypes of the Beaver Mines Formation in the Burnt Timber Creek section at successive powers of the matrices.

	Markov chain property	Oscillating lithology or lithotype	Power of recurrence probability maxima	Eigenvalues*	Type of series
TYPE SECTION					
Grain size	Yes				
1m interval		None	--	P,C	Non-oscillating
2m interval		v.f. sst.	1	P,N	NON-oscillating
Lithotypes	Yes				
1m interval		None	--	P,C	Non-oscillating
2m interval		T3	1	P,N	Non-oscillating
SHEEP RIVER SECTION					
Grain size	Yes				
1m interval		None	--	P	Non-oscillating
2m interval		None	--	P	Non-oscillating
Lithotypes	Yes				
1m interval		None	--	P	Non-oscillating
2m interval		None	--	P	Non-oscillating

* P = positive real numbers
N = negative real numbers
C = complex numbers

Table 5-11. Summary of the results of the Markov analyses of the Blairmore Group.

	Markov chain property	Oscillating lithology or lithotype	Power of recurrence probability maxima	Eigenvalues*	Type of series
TYPE SECTION					
Grain size	Yes	fine sst.	1	P,C	Non-oscillating
1m interval		fine sst.	1	P,C	Non-oscillating
2m interval		claystone	1	P,N	1 oscillating lithology
		v.f. sst.	2		
Lithotypes	Yes				
1m interval		None	--	P,C	Non-oscillating
2m interval		TBM2	2	P,N	1 oscillating lithology
SHEEP RIVER SECTION					
Grain size	Yes				
1m interval		None	--	P,C	Non-oscillating
2m interval		siltstone	1	P,C	Non-oscillating
		fine sst.	1		
Lithotypes	Yes				
1m interval		?**	--	P,C	Non-oscillating
2m interval		SBM4	1	P,C	Non-oscillating
		SBM5	1		
BURNT TIMBER CREEK SECTION					
Grain size	Yes				
1m interval		None	--	P	Non-oscillating
2m interval		siltstone	2	P,N,C	1 oscillating lithology
		v.f. sst.	1		
		fine sst.	1		
Lithotypes	Yes				
1m interval		?**	--	P,C	Non-oscillating
2m interval		B4	2	P,N	Non-oscillating

* P = positive real numbers
N = negative real numbers
C = complex numbers

** Fluctuations in the 5th decimal place

Table 5-12. Summary of the results of the Markov chain analyses of Beaver Mines Formation.

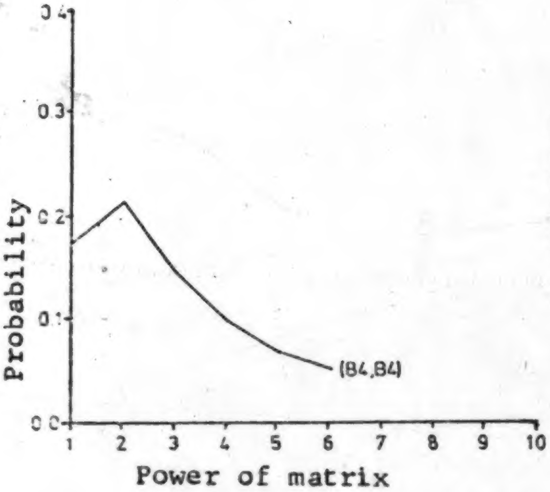


Figure 5-26. Recurrence probabilities of lithotype B4 of the Burnt Timber Creek section Beaver Mines Formation at the 2 metre sample interval.

patterns showed two almost independent patterns: a medium grained sandstone-fine grained sandstone alteration and a closed set of siltstone, claystone, and very fine grained sandstone.

The oscillating or cyclic nature of a lithology or lithotype was recognized by higher transition probabilities tracing oscillating paths toward equilibrium and eigenvalues which were negative real and/or complex numbers. However, to fit fully the definition of an oscillating series and therefore have geological cyclicity, the recurrence probability maxima of a lithology or lithotype must be at a power of the matrix other than one. Therefore, though a number of matrices had complex eigenvalues, they were defined to be non-oscillatory because the recurrence probability maxima were at the first power of the matrix.

The Blairmore Group, when analyzed as a complete entity in the type section and the Sheep River section, proved to be non-oscillatory.

This was true when the sections were coded according to lithology (grain size) or as lithotypes.

The Beaver Mines Formation, when considered separately, showed much more oscillatory behavior. All of the sections contained some oscillating lithology or lithotype which was so strongly damped as to be regarded as non-oscillatory. The type section is non-oscillatory except for the very fine grained sandstones which showed a period of recurrence of 4 metres both as a lithology and as lithotype TBM2. The Sheep River section is completely non-oscillatory. The Burnt Timber Creek section is non-oscillatory except for the siltstones which showed a period of recurrence of 4 metres both when coded as a lithology or as lithotype B4.

Schwarzacher (1975, p. 259) suggested that the existence of a negative eigenvalue in a transition matrix will produce an oscillation period of two units. He also suggested that this may be a function of the manner in which the sections were sampled for the transition matrices. In this chapter, recurrence maxima were found at the 2 metre sample interval yet no oscillations were present at the 1 metre sample interval. This could possibly be explained as being a result of the method of structuring the transition matrices and not a true period of recurrence.

CHAPTER 6

DEPOSITIONAL ENVIRONMENTS OF THE BLAIRMORE GROUP

6.1 Introduction

The Blairmore Group has been described as an alluvial plain succession in a number of previous papers (Norris, 1964; Glaister, 1959; Rapson, 1964; Mellon, 1967). This chapter represents an attempt to be more specific about the depositional environment of the group and to explain the successions and the sedimentary structures found in the sections measured.

In order to do this, models of fluvial processes will be examined briefly and a summary of the features of the Blairmore Group will be presented, followed by an interpretation of the measured sections.

6.2 Discussion on fluvial sedimentology

The ultimate distribution, character, and accumulation of fluvial sediments have numerous controls. It is necessary to consider a number of these before models can be constructed for comparative purposes.

Stream types

The shape of a stream channel is the result of the interaction of fluid discharge (amount and variability), sediment load (amount and calibre), channel width and depth, flow velocity, slope, and bed roughness (Leopold and Wolman, 1957). Schumm (1968) added the amount of vegetation in the source areas and the floodplains as a control and Allen (1965) suggested that the elements which influence these factors are climate, geology, and relief of the enclosing basin.

The most common plan view stream patterns (Figure 6-1) are braided, meandering, straight, and anastomosing (Miall, in press) with a continuous spectrum between these types. Table 6-1 summarizes the features of the four stream patterns.

Schumm (1968) classified rivers according to the type of sediment load carried. His types are suspension-load, bed-load, and mixed-load streams.

Braided streams are made up of two or more channels which flow around and over numerous alluvial islands and bars. They are best developed in alluvial fans and glacial outwash plains. High width/depth ratios, abundant sediment, high regional slopes, generally low sinuosities, highly variable discharge, and easily eroded banks typify a braided stream (Smith, 1970; Miall, in press).

Meandering channels are sinuous in a plan view. Discharge variability and channel slope is lower and the sediment calibre commonly is smaller than in a braided stream. Erosion is concentrated on the outer bank of the meanders which generally consist of cohesive floodplain deposits or, less commonly, earlier channel or point bar deposits. Deposition occurs mainly in the form of point bars which accrete laterally on the convex bank of a meander (Allen, 1965).

Straight channels have negligible sinuosity at bankful discharge (Allen, 1965), are not common naturally, and occur mainly on relatively gentle slopes (Miall, in press). Flume studies (Simons et al., 1965) and observations of natural streams (Harms and Fahnestock, 1965) have shown that at low flow stages the thalweg of a straight channel does trace a sinuous course between its banks. Sediment bars form on

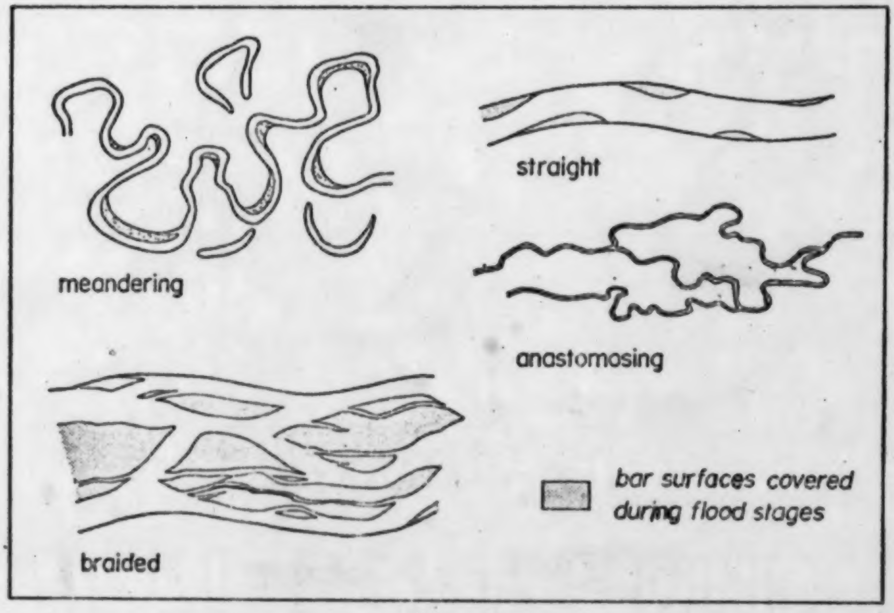

meandering
straight
anastomosing
braided
▨ bar surfaces covered during flood stages

Figure 6-1. Plan views of principal stream types (from, Miall, in press).

Type	Morphology	Load-type	Erosive behavior	Depositional behavoir
Meandering	single channels	suspension- or mixed-load	channel incision, meander widening	point bar formation
Braided	two or more channels with bars and small islands	bed-load	channel widening	channel aggradation, mid-channel bar formation
Straight	single channel with pools and riffles, meandering thalweg	suspension-, mixed-, or bed-load	minor channel widening and incision	side-channel bar formation
Anastomosing	two or more channels with large, stable islands	suspension-load	slow meander widening	slow bank accretion

Table 6-1. Summary of some of the characteristics of the principle stream types (after Miall, in press).

alternating sides of the channel and are the sites of deposition of sediment (Allen, 1965).

Anastomosing is a term which is becoming restricted to streams which have two or more, highly sinuous, stable channels with cohesive banks. The channels are separated by large, stable, vegetation covered islands (Miall, in press).

Moody-Stuart (1966) used the terms high- and low-sinuosity to differentiate between types of fluvial deposits. His high-sinuosity stream is equivalent to a meandering stream. Streams with straight patterns but few alluvial bars or islands were termed low-sinuosity and were considered to be intermediate between braided and meandering.

Hydrodynamic controls on sedimentation

Before models of fluvial facies can be built, the effect of flow upon various types of sediments and the resultant sedimentary structures must be investigated.

The velocity of a flow within a channel is subject to a number of controls (channel slope, water temperature, depth, and resistance to flow) and may be divided into lower and upper flow regimes with an intermediate transition zone (Simons, *et al*., 1965). The bedforms produced vary with flow velocity, flow depth, and sediment size.

Most of the studies of bedforms produced under varying flow conditions have been conducted using flumes. This has produced repeatible results over only a small range of flows and sediment sizes. The most recent graphic summary of such studies is by Harms *et al*. (1975) (see Figure 6-2). Ripples (small-scale structures) and dunes (large-scale structures) were long recognized in flume studies (Simons, *et al*., 1965).

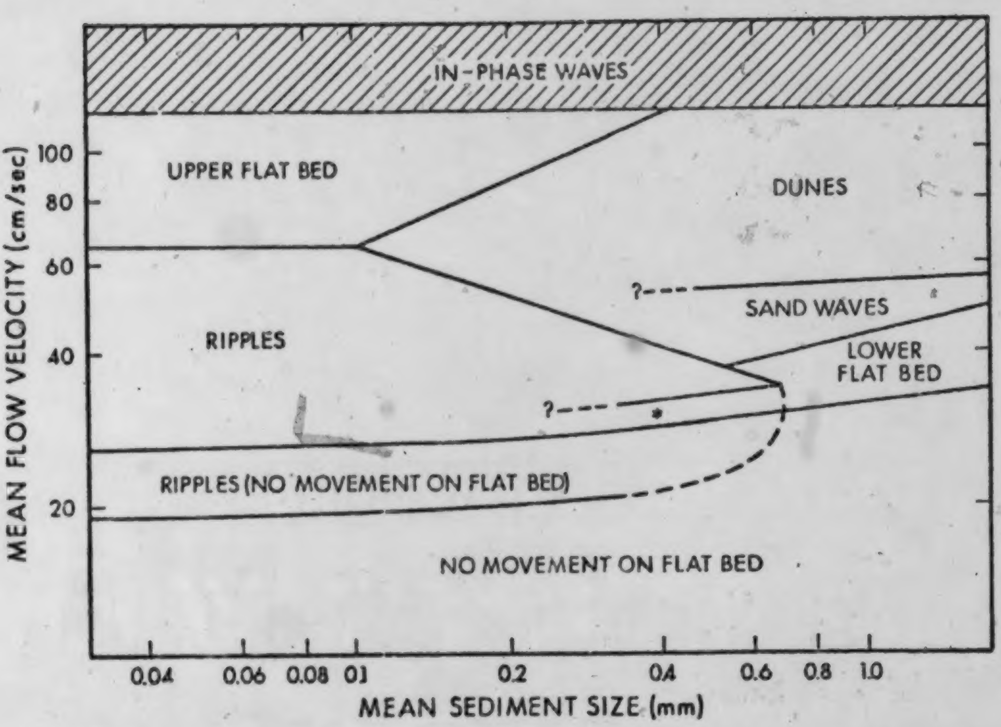


Figure 6-2. Schematic size-velocity diagram for a flow depth of 20 cm. Asterisk marks the field in which there is flat bed transport on an undisturbed bed but where ripples develop once the bed is disturbed (from Harms et al., 1975).

Harms, et al. (1975) recognized another large-scale bedform and used the term sand wave. The same authors noted that flat or plane bed transport and deposition is stable at two different ranges of flow velocity and sediment size: a lower plane bed and an upper plane bed.

Under the same set of increasing flow conditions, the sequence of bedforms which may be expected changes with the sediment size available. As can be seen in Figure 6-2, the sequence of bedforms produced under increasing flow velocities for silts and very fine sands (0.03 to 0.1 mm.) are no movement of sediment, then ripples, and finally the upper flat bed. For fine and medium sands (0.1 to 0.6 mm.) the sequence produced is from no movement to ripples to sand waves to dunes and finally to the upper flat bed. In sediment of coarse and very coarse sand ($>$ 0.6 mm.), ripples are not stable at any flow velocity and the sequence of bedforms observed under increasing flow are no movement to lower flat bed to sand waves to dunes to upper flat bed. The boundary between dunes and upper flat beds at this size range is at velocities and depths not attainable in flumes and is not included in Figure 6-2 (Harms, et al, 1975).

The stability of the various bedforms in relation to differing sediment sizes must be determined in order to interpret the flow conditions from the sedimentary structures. The change from lower to upper flow regimes was always taken at the boundary between dunes and upper flat beds (Simons, et al., 1965). The portion of Figure 6-2 designated as "in phase waves" is the range where antidunes are formed, and since antidunes are rarely recognized as preserved structures they are not discussed.

Common types of stratification

Small-scale trough cross-stratification is produced by migrating linguoid ripples as a result of in-filling of scours in the lee of the ripple (Harms and Fahnestock, 1965). Ripples of other configurations may produce other small scale sedimentary structures of various forms (Harms, *et al.*, 1975).

Large-scale trough cross-stratification is a product of migrating dunes (Harms and Fahnestock, 1965; Visher, 1972). Dunes are the most common bedform in sunuous or meandering rivers and are formed in sediment ranging in size from fine sand to gravel (Harms, *et al.*, 1975).

Large-scale tabular cross-stratification is produced by the avalanching of sediment down the lee slope of sand waves (Harms, *et al.*, 1975) and these bedforms are common in most rivers. Miall (in press) has divided braid bars (types of sand waves) into three main types: (1) longitudinal, (2) linguoid and transverse, and (3) point, side, and lateral bars. The linguoid and transverse bars (most typical of sandy braided rivers) have been shown to produce tabular cross-stratification by avalanche slope progradation (Smith, 1970, 1972, 1974; Miall, in press).

Horizontal stratification is produced by sediment transport and sedimentation over a plane or flat bed. For most sands and silts this is in the upper flow regime but for coarse and very coarse sands it may be in the lower flow regime as lower flat bed transport (Harms, *et al.*, 1975). This is not to be confused with parallel laminations produced by the gradual settling out of silts and clays from suspension in quiet water.

Alluvial facies models

Facies models for fluvial systems have been developed for comparative purposes between deposits. Thus far, the model for meandering rivers is the only one widely accepted, whereas fluvial systems show a complete gradation from meandering to braided and finally to flashy, ephemeral streams and sheetfloods on alluvial fans (Harms, *et al*, 1975).

Meandering fluvial facies model

The hydrodynamics, geomorphology, and sedimentology of meandering streams have been extensively investigated and described (Allen, 1965, 1970; Visher, 1965, 1972; Harms, *et al*., 1975; Walker, 1976). The deposits may be divided, as in most fluvial systems, into channel, channel-fill, and overbank deposits (Allen, 1965). (See Figure 6-3A)

Meandering is maintained by erosion of the concave bank of the meander and deposition on the inside of the meander as a point bar. The point bar accretion is lateral and downstream giving rise to the term "lateral accretion deposit" (Allen, 1965; Walker, 1976). At the base of a channel deposit is a channel lag deposit of the coarsest bed load along with coarse plant debris and large mud clasts. Above this is a fining-upward dequence of large-scale trough cross-stratified sands, grading into small-scale trough cross-stratification capped by overbank deposits. An early model (Allen, 1963) placed horizontally-bedded sands between the channel lag and the large trough cross-stratified beds with the sequence representing steadily decreasing flow conditions. Since then it has been recognized that horizontal bedding may be found anywhere in the channel sequence (Allen, 1970); channel depth, curvature, slope and width only need be changed slightly to produce flat beds as opposed

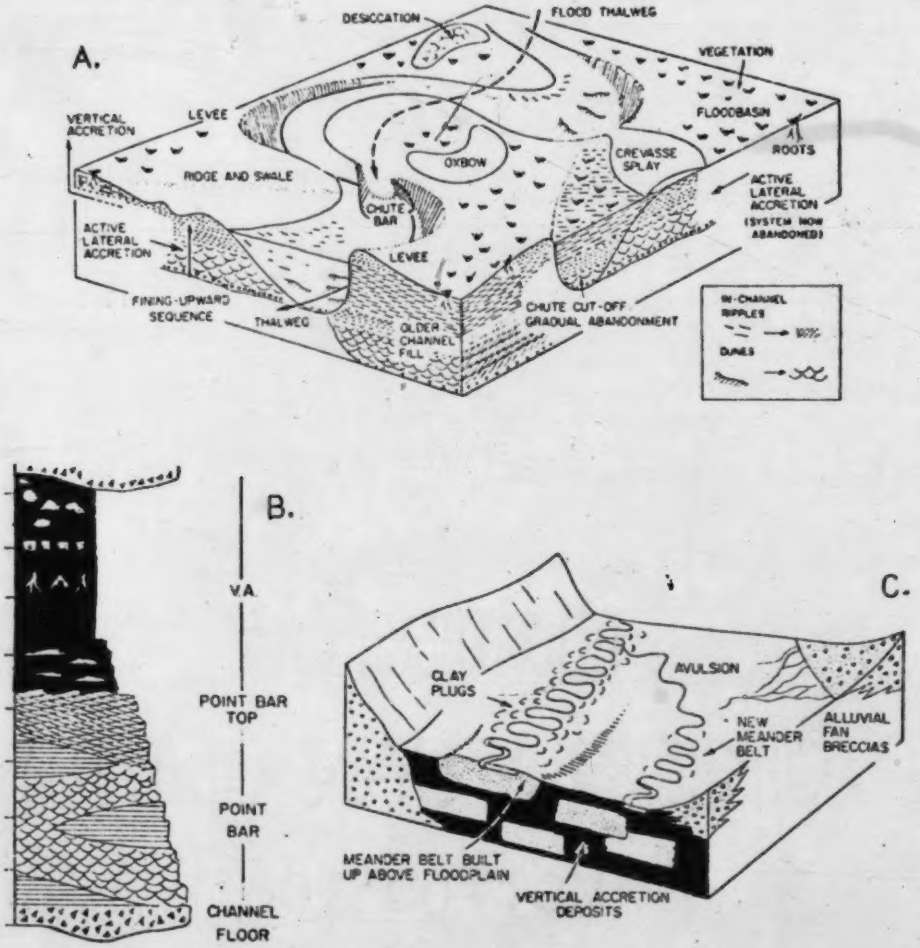

A.
DESICCATION
FLOOD THALWEG
VEGETATION
FLOODBASIN
ROOTS
VERTICAL ACCRETION
LEVEE
RIDGE AND SWALE
OXBOW
CREVASSE SPLAY
CHUTE BAR
ACTIVE LATERAL ACCRETION
ACTIVE LATERAL ACCRETION (SYSTEM NOW ABANDONED)
LEVEE
FINING-UPWARD SEQUENCE
THALWEG
OLDER CHANNEL FILL
CHUTE CUT-OFF GRADUAL ABANDONMENT
IN-CHANNEL RIPPLES
DUNES
B.
V.A.
POINT BAR TOP
POINT BAR
CHANNEL FLOOR
C.
CLAY PLUGS
AVULSION
NEW MEANDER BELT
ALLUVIAL FAN BRECCIAS
MEANDER BELT BUILT UP ABOVE FLOODPLAIN
VERTICAL ACCRETION DEPOSITS

Figure 6-3. A) Elements of a meandering stream and the associated sedimentary structures. B) Fining-upward model of a meandering river deposit. C) Floodplain model for a meandering river system. (from Walker, 1976).

to ripples or dunes. Allen also found that flat beds will form only in very gentle meanders (i.e., low sinuosity) and therefore occur only in some meandering rivers at high flood stages when the flood thalweg is less sinuous than the low flow thalweg. Planar-tabular cross-stratification is not common in meandering rivers but McGowen and Garner (1970) and Jackson (1975) have described planar foreset sedimentation on the avalanche faces of bars in meandering streams which are the equivalent to braided stream transverse bars.

The overbank deposits of a meandering stream are formed during and after high flood stages of the river. They take the form of levees, swale fills, crevasse-splays, and flood basin deposits and represent the build-up or "vertical accretion" of the floodplain (Allen, 1965). The grain size of the sediments decreases away from the finer sands to pure clays with increasing distance away from the stream. Stratification takes the form of small-scale ripples and parallel laminations. Vegetation growth is often intense on the floodplains and the deposits contain abundant organic remains and root traces. Flood waters may become ponded on the flood plain and form fresh-water lakes which contain invertebrate faunas and from which carbonates are deposited. Dessication often produces suncracks in the clays and silts. In arid to sub-humid environments [less than 30 inches of precipitation per year (Gary, et al., 1972)], caliche-like nodules may form by pedogenic processes in carbonate-rich soils (Allen, 1965, 1974a; Visher, 1965, 1972; Walker, 1976).

Crevasse-splay deposits are overbank deposits but may contain sediment that is of the same grain size as the channel deposits. This is possible through erosion during flooding that is deep enough to tap the bed load of the stream (Allen, 1965; Walker, 1976). Such deposits may show stratification comparable to that found in the channel sands.

The meandering river facies model (Figure 6-3B) describes a fining-upward sequence from channel lag through point bar to overbank deposits. In terms of the complete floodplain, the stream meanders over portions of the plain to produce elongate sand bodies bordered by overbank fines. In time, successive stream locations are abandoned and new locations occupied; this allows for the repetition of fining upward sequences in a vertical section (Figure 6-3C) (Allen, 1965; Visher, 1972; Walker, 1976).

Braided fluvial facies model

Models of the sedimentology of sandy braided stream deposits are not as well developed as those for meandering streams and most discussions are mainly comparisons of braided and meandering systems. The most complete synthesis of braided stream models was done by Miall (in press) in which four types of braided streams are described. Recent braided rivers have been examined in detail by Doeglas (1962), Coleman (1969), Collinson (1970), Smith (1970, 1974), and Williams and Rust (1969). There are even fewer documented examples of ancient braided rivers (Moody-Stuart, 1966; Smith, 1970; Cant and Walker, 1976; Miall, 1970, 1976).

The controls on the deposition of braided stream sediments are easily eroded banks, highly variable discharge rates with high flood velocities, high slope, and abundant bed load sediment supply (Smith, 1970). Braiding is initiated when the stream deposits the sediment sizes it is unable to carry or when the stream is not competent to move the total sediment supply. Channel bars build around this dropped portion of the load (Leopold and Wolman, 1957). The sediment supply is generally coarser than in a meandering stream and the coarse load is deposited over the whole of the floodplain.

The channel deposits take their characteristics from the bedforms which are found in the channel; dunes and sand waves of various types. The dunes produce large-scale trough cross-stratification which may also be found in parts of some bars (Smith, 1974; Walker, 1976). Longitudinal bars [confined to bars of gravel (Miall, in press)] consist of crude horizontal bedding with overall fining-upwards and fining-downstream patterns. This type of stratification becomes less abundant distally in a braided stream (Smith, 1970). Transverse and linguoid bars have well developed avalanche faces which are the areas of formation of large-scale tabular cross-stratification (Smith, 1970, 1971a, 1971b, 1972; Harms, et al., 1975; Walker, 1976). Point bars are uncommon in braided streams (Walker, 1976) (Figure 6-4A), although side or lateral bars have been described in braided streams (Collinson, 1970).

Overbank or vertical accretion deposits of braided systems are of minor importance and are rarely preserved. Due to the ease of migration of the channels, the resultant rapid shifting of channel positions and the coarseness of the sediment load, any fines that had been deposited would not likely be preserved.

Miall (in press) has described four types of braided river systems and named them after the streams in which the characteristics of each were first described: the Scott, Donjek, Platte, and Bijou Creek types. The Scott type is gravel dominated and accretion is by superimposition of successive longitudinal bars in proximal streams. The other three types are sandy systems.

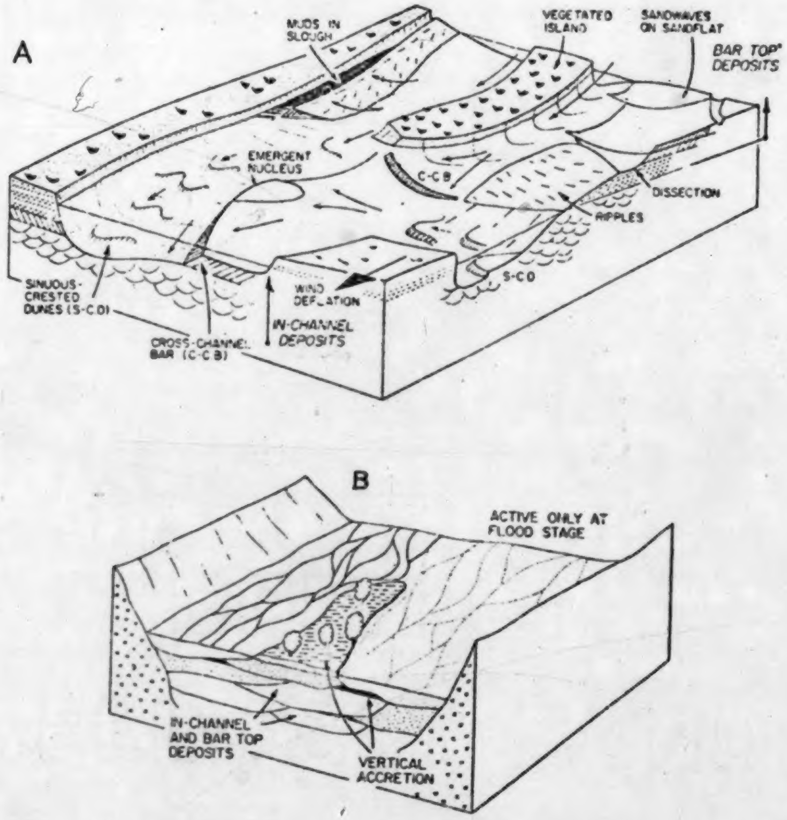

A
MUDS IN SLOUGH
VEGETATED ISLAND
SANDWAVES ON SANDFLAT
BAR TOP' DEPOSITS
EMERGENT NUCLEUS
C-CB
DISSECTION
RIPPLES
SINUOUS-CRESTED DUNES (S-C.D)
WIND DEFLATION
S-CD
IN-CHANNEL DEPOSITS
CROSS-CHANNEL BAR (C-C.B)
B
ACTIVE ONLY AT FLOOD STAGE
IN-CHANNEL AND BAR TOP DEPOSITS
VERTICAL ACCRETION

Figure 6-4. A) Elements of a braided stream and the associated sedimentary structures. B) Floodplain model for a braided stream system. (from Walker, 1976.)

The Donjek type forms a cyclic deposit with successive fining-upward cycles. The cycles may be extremely varied but all represent a decrease in energy upward. These cycles may be distinguished from similar cycles generated by meandering streams by the abundance of planar-tabular cross-stratification which is not common in meandering streams.

The Platte type shows no cyclicity and is composed of superimposed linguoid bar deposits. The result is an abundance of planar-tabular cross-bedded sands sometimes with gravel from longitudinal bars.

The Bijou Creek type was modeled after the flood deposits of Bijou Creek in Colorado as described by McKee, _et al_., (1967). The sediments deposited after 9 to 12 hours of flooding were sand-sized, from a few centimetres to at least 4 metres in thickness, and extended up to three-quarters of a kilometre laterally. The most charcteristic feature of the deposits was the predominance of horizontal bedding which was observed both on the floodplain and in the channel. The Bijou Creek model consists of superimposed catastrophic flood deposits which are mainly horizontally bedded units (upper plane bed) with succeeding planar cross-beds and ripples formed during waning flow. Severe flood events have been used by Bell (1968), Stanley (1968), and Miall (1970, 1973) to explain thick, massive to flat bedded sandstones in ancient fluvial sequences.

The model for the floodplain of a braided river would be lateral and vertical successions of the deposits described above with few, thin, discontinuous argillaceous overbank deposits (Figure 6-4B) (Allen, 1965; Walker, 1976).

The main distinguishing features between meandering and braided streams were summarized by Smith (1970) and Cant and Walker (1976): (1) ripple and dune trough cross-stratification dominate meandering stream deposits, whereas horizontal and tabular cross-stratification are more common in braided streams, (2) braided streams more often contain abrupt variation in grain size, (3) thin shales and intraclasts occur more often in braided deposits, and (4) beds are thinner and more irregular in braided stream deposits. Miall (in press) noted these differences plus that the coarse member of a braided stream cycle forms a greater proportion of total cycle thickness than those generated by a meandering stream.

Straight stream facies model

Straight stream channels are not common in nature. As stated previously, the thalweg of a straight channel does trace a sinuous course within the channel and sand bodies, formed on alternating sides of the channel, migrate downstream (Allen, 1965, 1970). Allen (1965) suggested this type of stream would be free to sweep across the complete floodplain depositing an upward-fining sequence of channel deposits with each pass. Overbank fines would be thin and not laterally extensive (Figure 6-5). This model is not well understood and has not been recognized in the ancient record.

Moody-Stuart (1966) believed he had recognized the ancient deposits of a low-sinuosity stream which is equivalent to a straight stream channel with few alluvial islands. His facies model (Figure 6-5B) differs with Allen's model (1965) and some of the features follow. Moody-Stuart (1966) suggested a low-sinuosity stream will not migrate

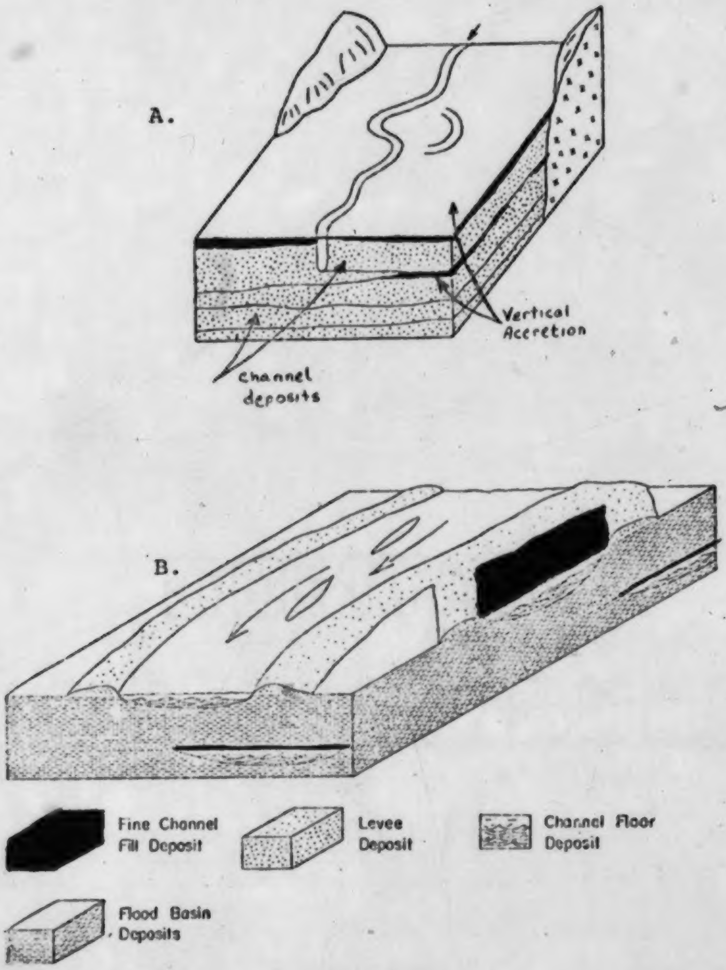

A.
channel deposits
Vertical Accretion
B.
Fine Channel Fill Deposit
Levee Deposit
Channel Floor Deposit
Flood Basin Deposits

Figure 6-5. Floodplain models for a straight channelled stream by (A) Allen (1965) and by (B) Moody-Stuart (1966).

laterally across a floodplain but will aggrade vertically with in a confined belt. As the channel system aggrades the channel would become wider and shallower since the channel banks would consist of sands which have very low cohesion. The channel will be diverted to a new location by avulsion after aggradation had raised the river bed above the level of the floodplain. Evidence of levees would be found only at the edges of channel sand bodies. Stream current directions would be normally distributed around the long axis of the stream whereas much more variation would be expected in a meandering stream.

Cyclic fluvial deposits

In the previous discussion concerning the meandering stream model, the term fining-upward sequence was used. Often, fining-upward cycle or cyclothem is used instead (Allen, 1965, 1970; Belt, 1968; Read, 1969; and many others). The terms cycle and cyclothem were avoided in this discussion because of the use of Schwarzacher's (1969) definition of geological cyclicity (see Chapter 2).

Most papers which are concerned with the cyclicity of a sequence of rocks contain suggestions about the controls on the cyclic processes. Some authors who have summarized and commented on these controls are Merriman (1964), Duff, *et al*. (1967), and Schwarzacher (1975). Beerbower (1964) suggested that cyclic or cyclothemic deposition is to be expected in a fluvial environment. The following discussion is based on his arguments and the terms cycle and cyclothem are used in the usual sense meaning one fining-upward sequence of strata, the characteristics of which occur repeatedly in a single section. This definition is designated as fluvial cyclicity as opposed to geological cyclicity.

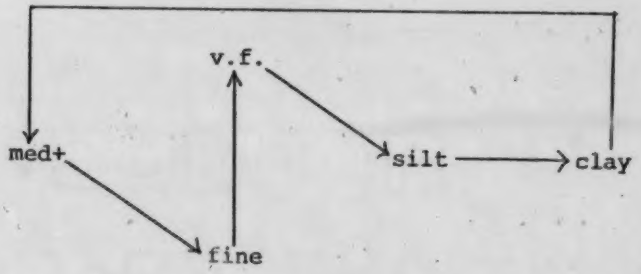
The controls on alluvial plain cyclicity were divided into internal (autocyclic) and external (allocyclic) factors (Beerbower, 1964). Autocyclicity is produced by channel migration and cut off, crevassing, and channel diversion. Beerbower concluded that cyclic deposits could be produced by this type of energy redistribution on the floodplain. Also all alluvial plains are subject to autocyclic sedimentation but cycles are only recorded or preserved when subsidence and compaction are rapid enough to carry the deposits to a position below the level of erosion. The cycles would be cyclothemic, that is gradually fining-upwards and abruptly overlain by coarse material at the base of another cyclothem.

The mechanisms of allocyclicity are varying discharge, load, and stream slope. These may vary due to variation in sea level, climatic changes, spasmodic source area elevation, and spasmodic subsidence of the depositional basin. These variations may produce cyclic deposits but, again, they will only be preserved if subsidence is sufficiently rapid.

As in most things there are complicating factors. Beerbower (1964) points out that with a number of these controls acting concurrently, cyclic characteristics may be intensified or obliterated as the controls go in and out of phase with each other. While developing these ideas, Beerbower acknowledged that he had made three assumptions which may not always be valid: (1) the depositional basin subsided uniformly over its whole extent, (2) compaction was uniform in all the sediments, and (3) alluvial plain topography did not restrict access of streams from any part of the plain. The opposite of these assumptions is often true in a depositional basin which in turn modifies the effects of the cyclic mechanisms and influences the deposition of fluvial sediments.

The point of this discussion is to show that alluvial plains naturally produce cyclic sedimentation and the absence or the poor development of such cyclicity should be investigated. Also, some ideas on the controls should be proposed.

The transition pattern produced from an autocyclicly deposited sequence should clearly show a succession of finer grained sediments upward abruptly succeeded by another cycle of the same type. Using the format of this study, the pattern would be:



6.3 Summary of the depositional features of the Blairmore Group

As discussed in Chapter 3, the Blairmore has long been recognized as an alluvial plain deposit. In addition to the sedimentary features of the group itself, further evidence is available from correlative units. Equivalent strata in the southern plains of Alberta (Brown, 1976) and Saskatchewan (Leung, 1976) have been shown to be fluvial in origin. To the north, the Luscar and Mountain Park facies of the Blairmore Group are also fluvial but also there is evidence of deltaic activity (Holter and Mellon, 1972). The reader is referred to Williams and Stelck (1975) for a regional paleogeographic discussion.

Another salient point concerning Blairmore deposition that must be reiterated is the active tectonism to the west and southwest of the West Alberta Basin during Blairmore time. (See the discussion on tectonism in Chapter 3.)

The graphic logs of the measured sections are presented in Figures 6-6, 6-7, and 6-8 with an interpretive division into channel (including flood deposits) and overbank deposits. The following is a description of the section subdivisions and reasons for the divisions. Chapter 4 contains more complete descriptions of the sections.

Overbank deposits

In the three sections--Type section (Figure 6-6), Sheep River (Figure 6-7), and Burnt Timber Creek (Figure 6-8)--an abundance of overbank deposits are evident. The features of these deposits are common to all three of the sections.

The most obvious characteristic is the interbedded succession of sediment ranging in grain size from medium grained sand to clay. The sandstones are thinner than the finer sediments and could be ascribed to levee or crevasse-splay or flood deposits. The siltstones and claystones show extremely varied thicknesses of a few decimetres to a few metres. Rapid vertical alternation of grain size was also observed.

Cross-bedded sandstones about 3 metres thick were observed within thick sequences of overbank deposits (for example, above C2 on the Sheep River log and above C5 on the Burnt Timber Creek log). These may be thin channel deposits, crevasse-splay deposits, or the result of severe flood events. The number of interbedded sandstones in the overbank deposits suggests that access to the floodplain was relatively easy and flooding was a common occurrence.

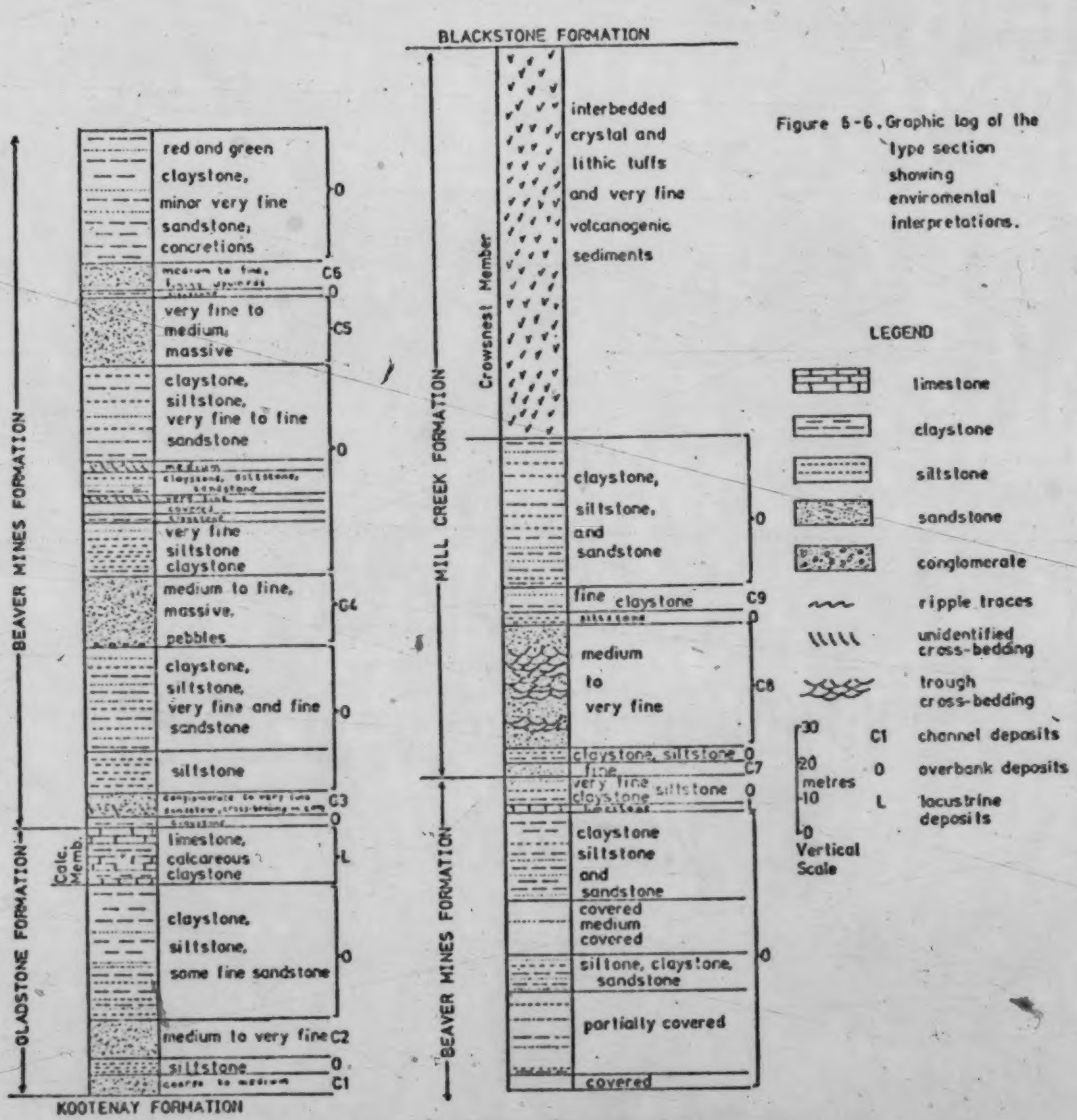

BLACKSTONE FORMATION
Crowsnest Member
interbedded crystal and lithic tuffs and very fine volcanogenic sediments
MILL CREEK FORMATION
claystone, siltstone, and sandstone
0
fine claystone
C9
siltstone
0
medium to very fine
C8
claystone, siltstone
0
fine
C7
very fine claystone siltstone
0
limestone
L
BEAVER MINES FORMATION
claystone siltstone and sandstone
covered medium covered
siltone, claystone, sandstone
partially covered
covered
0
red and green claystone, minor very fine sandstone; concretions
0
medium to fine,
C6
0
very fine to medium, massive
C5
claystone, siltstone, very fine to fine sandstone
medium
claystone, siltstone, sandstone
very fine
covered
siltstone
very fine siltstone claystone
0
medium to fine, massive, pebbles
C4
claystone, siltstone, very fine and fine sandstone
siltstone
0
conglomerate to very fine sandstone, cross-bedding
C3
siltstone
0
GLADSTONE FORMATION
Calc. Memb.
limestone, calcareous claystone
L
claystone, siltstone, some fine sandstone
0
medium to very fine
C2
siltstone
0
coarse to medium
C1
KOOTENAY FORMATION
LEGEND
limestone
claystone
siltstone
sandstone
conglomerate
ripple traces
unidentified cross-bedding
trough cross-bedding
30
20
10
0
metres
Vertical Scale
C1 channel deposits
0 overbank deposits
L lacustrine deposits

Figure 6-6. Graphic log of the type section showing enviromental interpretations.

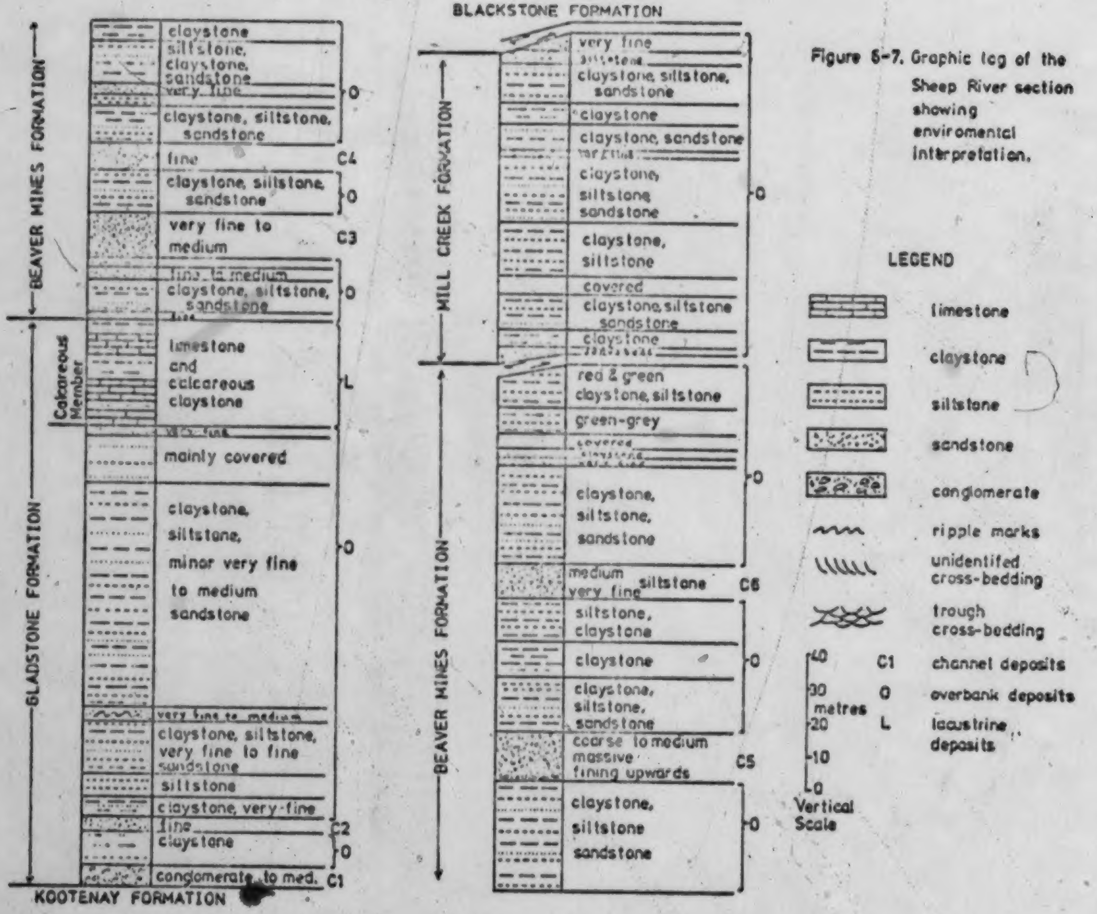

BEAVER MINES FORMATION
GLADSTONE FORMATION
Calcareous Member
KOOTENAY FORMATION
claystone
siltstone, claystone, sandstone
very fine
claystone, siltstone, sandstone
fine
claystone, siltstone, sandstone
very fine to medium
fine to medium
claystone, siltstone, sandstone
limestone and calcareous claystone
mainly covered
claystone, siltstone, minor very fine to medium sandstone
very fine to medium
claystone, siltstone, very fine to fine sandstone
siltstone
claystone, very-fine
fine
claystone
conglomerate, to med.
O
C4
O
C3
O
L
O
C2
O
C1
BLACKSTONE FORMATION
MILL CREEK FORMATION
BEAVER MINES FORMATION
very fine
siltstone
claystone, siltstone, sandstone
claystone
claystone, sandstone
claystone, siltstone, sandstone
claystone, siltstone
covered
claystone, siltstone sandstone
claystone
red & green claystone, siltstone
green-grey
covered
claystone, siltstone, sandstone
medium
very fine
siltstone
siltstone, claystone
claystone
claystone, siltstone, sandstone
coarse to medium massive fining upwards
claystone, siltstone sandstone
O
O
C6
O
C5
O
LEGEND
limestone
claystone
siltstone
sandstone
conglomerate
ripple marks
unidentifed cross-bedding
trough cross-bedding
C1 channel deposits
O overbank deposits
L lacustrine deposits
40
30
metres
20
10
0
Vertical Scale

Figure 5-7. Graphic log of the Sheep River section showing enviromental interpretation.

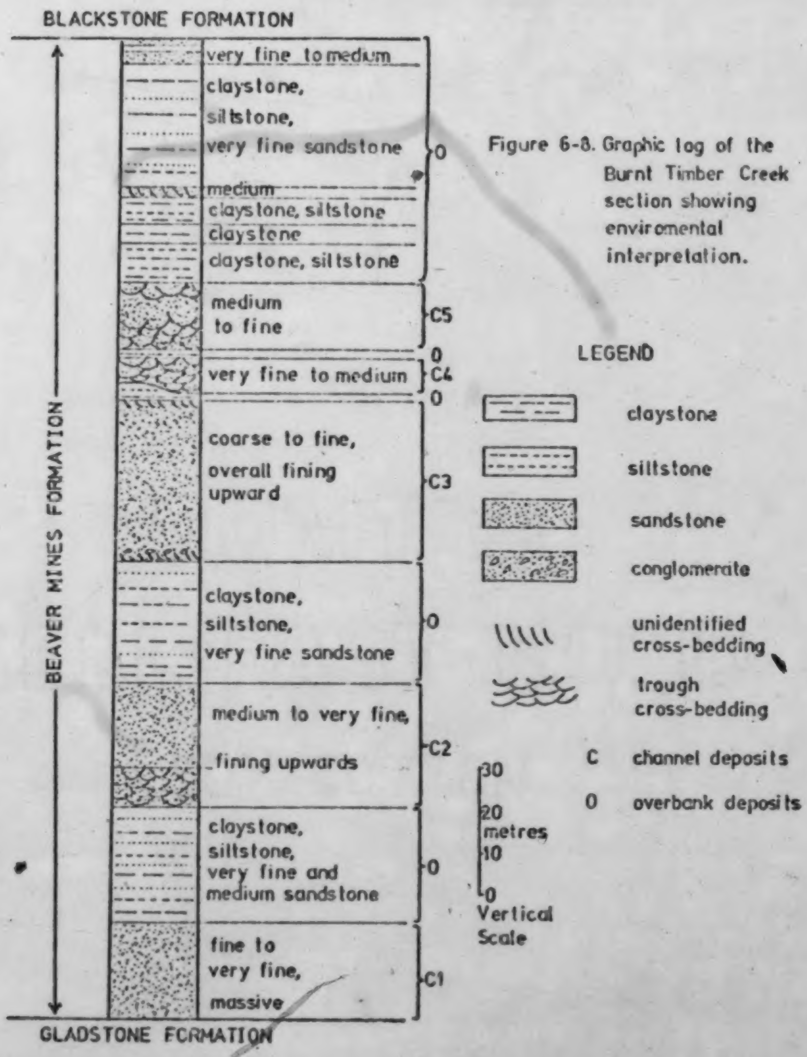

BLACKSTONE FORMATION
very fine to medium
claystone,
siltstone,
very fine sandstone
medium
claystone, siltstone
claystone
claystone, siltstone
O
medium
to fine
C5
O
very fine to medium
C4
O
coarse to fine,
overall fining
upward
C3
claystone,
siltstone,
very fine sandstone
O
medium to very fine,
fining upwards
C2
claystone,
siltstone,
very fine and
medium sandstone
O
fine to
very fine,
massive
C1
BEAVER MINES FORMATION
GLADSTONE FORMATION
LEGEND
claystone
siltstone
sandstone
conglomerate
unidentified
cross-bedding
trough
cross-bedding
C channel deposits
O overbank deposits
30
20
metres
10
0
Vertical
Scale

Figure 6-8. Graphic log of the Burnt Timber Creek section showing enviromental interpretation.

The siltstones and claystones sometimes showed red or mottled red and green coloration indicating oxidizing conditions on the floodplain. Mudcracks, due to dessication, were observed though not frequently. Organic debris occurs in all lithologies but not abundantly in any one rock type or overall. The floodplain did support vegetation but not dense, stable stands or swamps. Calcareous concretions or nodules were observed in claystones and siltstones and rarely in very fine grained sandstones. Formed in soil horizons, these concretions show that parts of the floodplain were isolated from any clastic deposition for extended periods of time and the area had only moderate mean annual temperatures and low to moderate mean annual amounts of precipitation (Allen, 1974a).

The Calcareous Member of the Gladstone Formation, the limestone at the top of the Beaver Mines Formation in the type section, and the transported algal balls in the Sheep River section, show that lakes were present on the floodplain, an interpretation confirmed by the presence of fresh-water invertebrate fossils in the sediments.

Channel deposits

The basic criteria for the identification of the channel deposits were the thicknesses and grain sizes of the units. The channel units are easily recognized and are denoted on the graphic logs as C1, C2, etc. Identification of the sedimentological processes which were operational during active channel deposition is more difficult.

The outstanding feature of many of the thick sandstones in the measured sections was the lack of any observable sedimentary structures. These sandstones are described as massive though they may have been horizontally bedded in part or structures that were present were not recognizable. Some of these massive sandstones show a fining-upward trend (type section: c6; Sheep River section: C5; Burnt Timber Creek Creek section: C3), others have fluctuating grain size distributions in a vertical profile (type section: C1, C2, C4, C5; Sheep River section: C1, C3, C6; Burnt Timber Creek section: C1), and the rest are of uniform grain size perhaps with thin interbeds of another lithology (type section: C7, C9; Sheep River section: C4).

The remaining channel units are cross-bedded at least in some portion of the unit (type section: C3, C8; Sheep River section: C2; Burnt Timber Creek section: C2, C3, C4, C5). The cross-stratification which was observed was large- or small-scale trough cross-stratification or else the exposure was such that the type could not be identified.

Most of these channel units are abruptly succeeded by overbank fines. If the change was found to be gradational, the gradation was over a very small vertical distance. Relief due to scouring at the base of the channel units was only a matter of a few centimetres with one exception, that of C4 on Burnt Timber Creek, where the sandstone had eroded approximately 4 metres into the underlying claystone.

The massive to horizontally-bedded sandstones were deposited under upper flow regime conditions. A flood event or a shallow flow depth would have produced the necessary conditions to yield plane beds.

Deposition of the large-scale trough cross-stratified sandstones was by migrating dunes under lower flow regime conditions. The trough cross-beds observed in the type section (C8) and the Burnt Timber Creek section (C4, C5) are interbedded with massive sandstones and bear the greatest resemblance to point bar deposits. These alternations of sedimentary structures could have been caused by changing flow depth or flow velocity.

Markov analysis and transition patterns

The results of the Markov analysis presented in Chapter 5 showed that all of the sections possessed a first-order Markov property. This was to be expected in an alluvial plain environment because of the upward variations in flow velocities and migrating stream channels.

The most obvious feature of the transition patterns (figured in Chapter 5) is the fining-upward trend, again, an expected feature of a fluvial deposit. However, there are no examples of the widely described, fluvial cyclothem: a basal erosional surface overlain by a coarse member of sandstone and succeeded by a fine member of chiefly siltstone with proofs of exposure, followed by another cyclothem (Allen, 1974b).

Figure 6-9 is a simplified version of the transition patterns in which the transitions with difference probabilities of less than 0.10 have been deleted. The most obvious feature is the absence of significant transitions from the finest lithologies (siltstone and claystone) to the coarser units (medium and coarser grained sandstone). Such transitions would be expected but in this case the thick sequences of alternating fine lithologies far outnumbered the transitions from the finest to coarsest sediments.

The Burnt Timber Creek transition patterns show two independent transition sets: one between fine and medium to coarser grained sandstone, and one from very fine sandstone to siltstone to claystone. This suggests a relative independence between the processes of channel

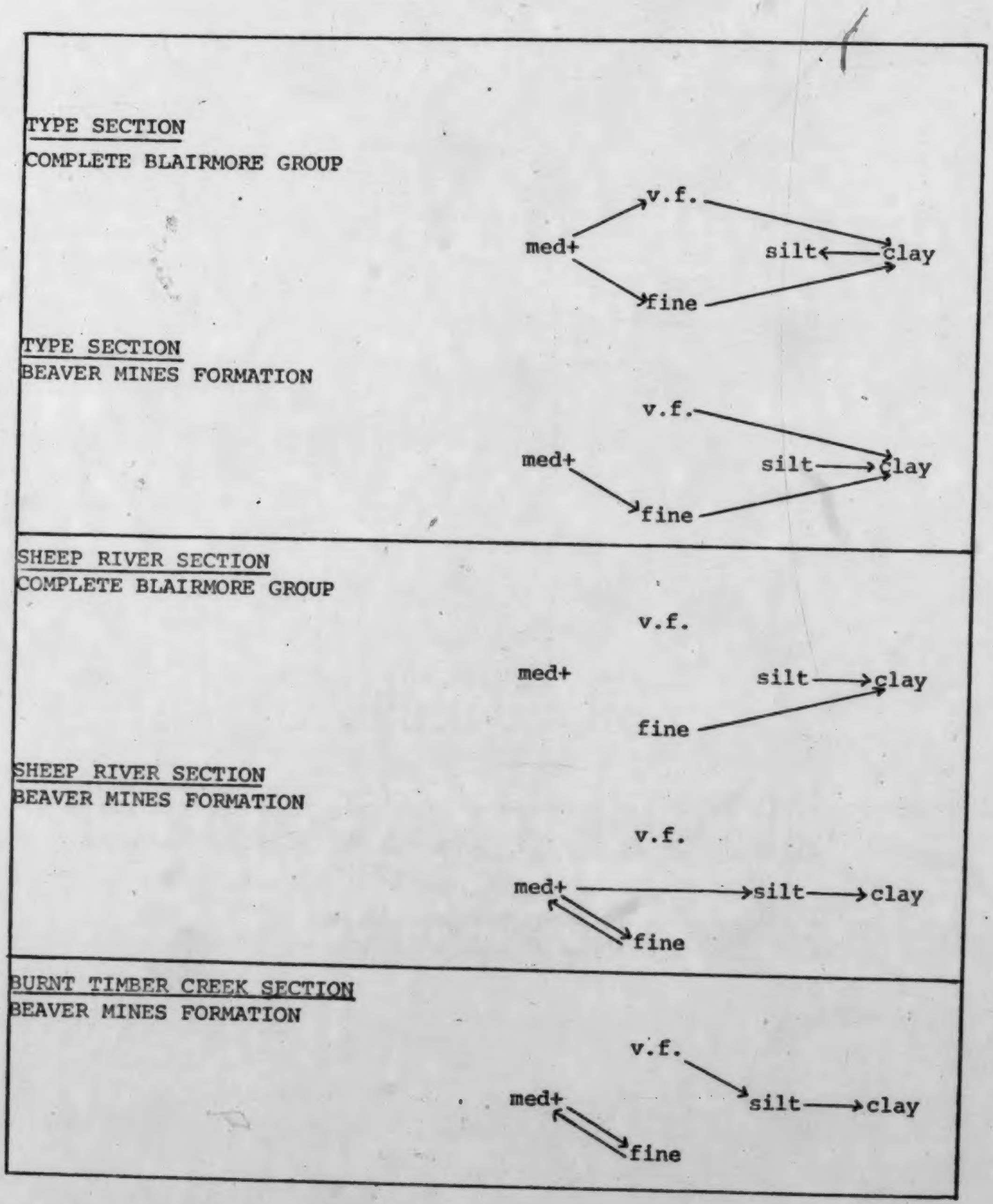

TYPE SECTION
COMPLETE BLAIRMORE GROUP
v.f.
med+
silt
clay
fine
TYPE SECTION
BEAVER MINES FORMATION
v.f.
med+
silt
clay
fine
SHEEP RIVER SECTION
COMPLETE BLAIRMORE GROUP
v.f.
med+
silt
clay
fine
SHEEP RIVER SECTION
BEAVER MINES FORMATION
v.f.
med+
silt
clay
fine
BURNT TIMBER CREEK SECTION
BEAVER MINES FORMATION
v.f.
med+
silt
clay
fine

Figure 6-9. Simplified versions of the transition patterns in Chapter 5. Difference probabilities of less than 0.10 are deleted from the patterns.

(fine and medium grained sandstone) and floodplain (the finer lithologies) deposition.

The type section has the most complete fining-upward transition patterns. In the Beaver Mines Formation of the type section, the pattern again suggests two separate trends although they are not as well defined as in the Burnt Timber Creek section.

The Sheep River section is the most anomolous of the three sections. There is no lithology which is most likely to follow very fine grained sandstone (both patterns) or medium grained sandstone (complete section only). The randomness of the lithologies may possibly be explained by the stream having had easy access to the floodplain, allowing sand to have been deposited at irregular intervals during flooding. With this type of deposition as well as deposition in the stream channel, actual transitions in the sections could have been to any one of a number of lithologies without any one transition being dominant. The succession of the fine grained sandstone followed by claystone in the complete section and medium grained sandstone followed by siltstone in the Beaver Mines portion of the section could be further evidence for this. In the Beaver Mines Formation, the medium grained sandstones show the above association as well as an in-channel deposition association with the fine grained sandstones.

Fluvial cyclicity

The classical fluvial cyclicity is not present in the Blairmore Group in the sections studied. A combination of Beerbower's (1964) autocyclic and allocyclic controls appear to have modified the expected fluvial fining-upward sequence.

In terms of autocyclicity, abrupt channel diversions seem to have been the dominant process of energy redistribution on the floodplain. This is suggested by the sharp contacts between channel and overbank deposits.

The allocyclic controls (varying discharge, load, and slope) may have had considerable influence on the sedimentation pattern. The most obvious cause of this would have been the Columbian tectonic activity, including thrust faulting, to the west and southwest. Tectonic pulses would have repeatedly raised the elevation of the source areas; subsequently, the rates of erosion, the stream slope, and the sediment load would have increased at irregular intervals.

The three formations which comprise the Blairmore have extremely different composition which suggests that tectonism had a major influence on the Blairmore at least at the scale of formations by exposing new source areas of differing composition. (See Figure 3-1.) The hiatuses between the formations in the Crowsnest Pass area have been explained by quiescent periods of tectonism (Price and Mountjoy, 1970). It is suggested that the tectonic activity had a lesser influence on the Blairmore on a within-formation scale which caused variations in stream slope and sediment supply. The immature composition of the Blairmore sandstones and the high-energy flood deposits described previously may be evidence for this tectonic influence.

Other features mentioned by Beerbower (1964) probably influenced the alluvial plain sequence as well. Irregular basinal subsidence and irregular floodplain access due to topography on the plain were probably strong factors on the control of sites of deposition and the ease with which a channel could migrate over the floodplain. The abundance of overbank sediments shows that channel locations were stationary for extended periods of time.

The lack of fluvial cyclicity can be explained by a combination of autocyclic and allocyclic controls. In terms of allocyclicity, channel positions were stable for extended periods of time and channel diversion was abrupt. The active tectonism to the west disrupted the autocyclic factors by altering stream slopes and loads.

6.4 Interpretation and summary

The Blairmore Group was deposited on a broad alluvial plain of low relief. The climate was hot and semi-arid to sub-humid with only low to moderate amounts of annual precipitation. This is supported by the presence of caliche-like nodules in the Blairmore.

The lack of vegetal remains in the Blairmore strata suggests that the amount of vegetation on the floodplain was sparse, especially when the Blairmore is compared to the underlying Kootenay Formation with its thick coal seams. With the abundance of overbank deposits in the Blairmore, surely coal deposits would have been preserved if vegetation growth had been lush. A climatic change to drier conditions from the Kootenay to Blairmore may explain the lesser growth of vegetation. The rising mountains to the west may have caused a rain shadow affect lowering the amounts of precipitation. This suggested paucity of vegetation cannot be applied to the whole of the present southern Foothills. McLean (1977) has reported the outcropping of a coal seam on Waiparous Creek which is located between the Sheep River and Burnt Timber Creek sections. The lateral extent of this seam has not been determined.

The large proportion of overbank sediments in the Blairmore and the thickness of channel and overbank facies packages suggests the channel positions were stable for extended periods of time. It is postulated that the stream positions were stable within narrow belts; the sandstone bodies which have been identified as channel deposits are multistory deposits of a succession of channel positions within the same belt. While the multistory channel belts were being deposited, thick overbank sequences were being formed on other parts of the floodplain.

Once the channel system had begun to flow in previously deposited channel sands, it would tend to stay within that belt instead of migrating laterally. The channel sands would form banks of very low cohesion and would be very easily eroded whereas the adjacent floodplain deposits would be more cohesive and would tend to retain the channel in the same position (Beerbower, 1964; Schumm, 1968b). Vegetation that was present on the floodplain would have been concentrated on the edges of the channel belt and would have increased the cohesion and resistance to erosion of the edges of the channel belt (Schumm, 1968a). With time, the channel system aggraded vertically until the river bed was raised above the level of the floodplain and diversion of the whole channel belt to a new location was by avulsion (Beerbower, 1964; Moody-Stuart, 1966).

The channels themselves were probably intermediate between meandering and briaded. As the channels continued to flow within the channel belt they would tend to become wider and shallower because of the lack of bank cohesion (Beerbower, 1964; Moody-Stuart, 1966). With the shallower flow depth, it is possible that horizontal bedding would have become the predominant sedimentary structure (Allen, 1970). With the suggested lack of vegetation, erosion rates and run-off would have been high during Blairmore time and the incidence of severe flooding such as the type described by McKee, et al. (1967) would have been very likely and would have produced horizontal bedding.

The number of overbank sands indicate that during severe flood events flood waters were spread over large areas of the floodplain. After the flood event, the main flow returned to the previous channel belt. The calcareous concretions formed in soil horizons and the carbonate units indicate parts of the floodplain were isolated from any influx of clastic material for long periods of time.

This model of deposition for the Blairmore does not fit the meandering or braided stream facies models. The proposed model of stable belts of multistory channel deposits which divert by avulsion is somewhat similar to Moody-Stuart's (1966) model for low-sinuosity streams which he suggested are intermediate between braided and meandering. Comparison of the Blairmore channel units with the Bijou Creek type of flood deposits also shows a number of similar features including the dominant sedimentary structure, the amount of plant cover, and the climatic conditions.

The lack of fluvial cyclicity was caused by the interaction of autocyclic and allocyclic controls. The lack of lateral migration of stream positions and channel diversion by avulsion do not provide the gradual facies transitions necessary for fluvial cyclicity. The main allocyclic control was the active tectonism to the west and southwest which caused irregular source area elevations, stream slopes, and sediment supplies.

The inferences drawn in this study are applicable only to the three measured sections. The conclusions are not realistic for the central and northern Foothills of Alberta where strata equivalent to the Blairmore Group are coal-bearing and have evidence of marine incursions. The Blairmore in the southern Foothills is highly variable in its character and the preceding interpretations may only be applicable in a very general sense to the group on a regional scale.

CHAPTER 7

SUMMARY AND CONCLUSIONS

Conclusions from Markov analyses

The Blairmore Group in the type section and the Sheep River section and the Beaver Mines Formation in these sections plus the Burnt Timber Creek section all possessed a first-order Markov property at a 99.9% level of confidence.

The transition patterns derived from the transition matrices all showed some variant of a fining-upward trend. These trends were always truncated however, in that transitions from the finest to coarsest lithologies were random or nearly random. A number of patterns displayed two almost-independent sequences: one between the coarser lithologies and the other among the finest lithologies.

The Blairmore Group was found to be non-oscillatory in the type and Sheep River sections. The Beaver Mines Formation also showed no geological cyclicity in the Sheep River section. In the type section, it was found that the Beaver Mines lithology of very fine grained sandstone (lithotype TBM2) had a period of recurrence of 4 metres, while the other lithologies were non-oscillatory. In the Burnt Timber Creek section, the lithology of siltstone (lithotype B4) in the Beaver Mines Formation should be expected to occur at 4 metre intervals while the rest of the lithologies had no period of recurrence. This apparent oscillatory behavior may be only a function of the sampling method used for the transition matrices.

Conclusions on the depositional environment

The Blairmore Group, as represented in the three measured sections, was deposited on a broad alluvial plain of low relief east of the rising Rocky Mountains. The channel positions were stable within narrow channel belts for extended periods of time which produced multistory channel deposits. The streams were intermediate between braided and meandering and deposited sediment under both upper and lower flow regime conditions. The stable channel belts allowed (1) great thicknesses of overbank sediments to accumulate, (2) pedogenic process to form calcareous concretions, and (3) fresh-water lakes to develop on the floodplain. Catastrophic flood events deposited horizontally-bedded sands in the channel belts and spread clastic detritus of widely varying grain size over large parts of the floodplain. The climate was hot and semi-arid to sub-humid with a paucity of vegetation on the floodplain.

The group shows a fining-upward trend but fluvial cyclicity is not present in the sections. The stable channel belts and the disruptive tectonic influence did not allow gradual migration of stream positions nor gradual vertical facies changes necessary to show cyclicity. The abundance of overbank fines mixed with flood-deposited sands subdued the transitions from the fine to coarse lithologies, producing truncated sequences. The separation of the transition patterns into two sets reinforces the idea of the separation of floodplain and channel processes as suggested by the stable channel belt model.

Conclusions on methodology

Detailed petrographic descriptions of samples by binocular microscope were found to be of no practical value for defining lithotypes using a cluster analysis approach. Sufficient petrographic information could be obtained by estimation of the percentages of dark and light minerals using a binocular microscope with slabbed samples.

The grain size of the sample dominated the groupings of samples in the cluster analyses. This was a function of the weighting applied in the coding, similarity among samples of the same grain size, and the limited number of clusters which could be used in a valid Markov chain analysis.

The results of the unweighted pair-group cluster analysis using Jaccard's coefficient was of extremely limited use in this study. The amount of time and money spent on this analysis was not justified since essentially the same results were achieved using classification by grain size alone.

Recommendations

The Blairmore Group should be investigated further to provide a more detailed sedimentological interpretation of the strata. Emphasis should be placed on sedimentary structures, depositional environments, paleocurrent analysis, and lateral trends of the channel sandstones. The differences between the coal-bearing strata in the northern Foothills and the generally barren Blairmore strata of the southern Foothills should be examined further and the gradational area between the two areas, in the vicinity of the Red Deer River, should be studied to determine if any evidence could be found to support basement control on Cretaceous sedimentation as suggested by Stelck (1975).

Studies using the different methods of structuring Markov chains should be made using actual stratigraphic sequences to assess their usefulness in something other than simulation runs. It is possible that there may be other autoregressive models (Schwarzacher, 1975) of use in analyzing stratigraphic data. More use of Schwarzacher's (1969, 1975) suggestions about geological cyclicity should be made on real sections to further investigate the meaning of eigenvalues and how the results may be interpreted sedimentologically and environmentally.

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APPENDIX A.

DETAILED DESCRIPTIONS OF THE MEASURED SECTIONS

Abbreviations used to indicate range of grain size:

c	clay
s	silt
vf	very fine sand
f	fine sand
m	medium sand
crs	coarse sand
vcr	very coarse sand
12 mm	size of pebbles in millimetres

Abbreviations used to indicate range of clast roundness:

va	very angular
a	angular
sa	subangular
sr	subrounded
r	rounded
wr	well rounded

TYPE SECTION

Kootenay Formation

Interbedded quartzose sandstone, dark grey shale and coal

Blairmore Group

Gladstone Formation

Sample Number	Thickness (metres)	Position (metres from base)	Description
G1-1	3.05	2.0	Sandstone, medium (f-crs) grained; moderate sorting; subangular (a-sr) clasts; 0% carbonaceous material; medium light grey, weathering brown; sharp unconformable lower contact; resistant.
	2.0		Covered.
G2-1	1.5	6.5	Siltstone; (s-vf); well sorted; angular clasts; 0% carbonaceous material; medium grey, weathering grey; highly fractured; moderately resistant.
	3.3		Covered.
G3-1	1.4	11.2	Same as G2-1.
G4-1	1.1	12.3	Sandstone, medium (f-crs) grained; moderate sorting; subangular (sa-sr) clasts; 2% carbonaceous material; small cross-beds; rare plant remains; medium grey, weathering grey brown; resistant; sharp to erosional lower contact.
G5-1	6.0	18.3	Sandstone, very fine (s-vf) grained; poor sorting; angular (va-sa) clasts; 2% carbonaceous material; medium light grey, weathering grey brown; resistant; gradational lower contact.
G6-1	2.0	20.3	Sandstone, very fine grained; well sorted; subangular (a-sr) clasts; medium light grey, weathering brown; moderately resistant; gradational lower contact.
G7-1	2.5	21.5	Sandstone, medium (f-crs) grained; well sorted; subangular (a-sr) clasts; 0% carbonaceous material; medium grey, weathering brown; moderately resistant; sharp lower contact.
G8-1	0.5	23.3	Siltstone; no sample; grey; recessive; highly fractured; sharp lower contact.
G9-1	2.0	25.3	Sandstone, very fine grained; well sorted; subrounded (sa-sr) clasts; 0% carbonaceous material; medium light grey, weathering grey; resistant; sharp lower contact.
G10-1	1.5	26.8	Sandstone, very fine (s-f) grained; moderate sorting; angular (a-sr) clasts; 0% carbonaceous material; medium light grey, weathering grey; moderately resistant; sharp lower contact.

A-4

Sample Number	Thick- ness (metres)	Position (metres from base)	Description
G11-1	1.9	28.7	Claystone; well sorted; reddish purple, weathering red and green; recessive.
G12-1	0.1	28.8	Siltstone; c-s; well sorted; medium light grey, weathering brown grey; moderately resistant.
G13-1	1.0	29.8	Siltstone; well sorted; grey, weathering green grey; recessive; sharp lower contact.
G14-1	2.0	31.8	Claystone; c-s; moderate sorting; reddish purple, weathering red and green; recessive; sharp lower contact.
G15-1	0.25	32.1	Claystone; c-s; well sorted; very light grey, weathering brown; moderately resistant; sharp lower contact.
G16-1	0.15	32.2	Claystone; no sample; grey; recessive; splintery; gradational lower contact.
G17-1	1.1	33.3	Sandstone; fine (vf-f) grained; well sorted; subrounded (sa-sr) clasts; 0% carbonaceous material; medium light grey, weathering grey brown; resistant; sharp lower contact.
G18-1	2.9	36.2	Claystone; no sample; grey; recessive; mainly covered.
G19-1	2.0	38.2	Claystone; c-s; well sorted; faint laminations; light grey, weathering brown; resistant; sharp lower contact.
	0.1		Covered.
G20-1	3.0	41.3	Claystone; c-s; well sorted; laminated; green and red, weathering red brown; recessive; sharp lower contact.
G21-1	0.1	41.4	Siltstone; c-s; well sorted; medium grey, weathering brown; moderately resistant; gradational lower contact.
G22-1	7.0	48.3	Claystone; grey; mainly covered; no sample.
G23-1	0.4	48.7	Siltstone; s-vf; poor sorting; angular (a-sa) clasts; abundant plant remains; light grey, weathering grey; 6% carbonaceous material; resistant; sharp lower contact.
G24-1	12.4	61.1	Claystone; mainly covered; recessive; sharp lower contact.
			Base of Calcareous Member
G25-1	1.9	63.03	Limestone; very fine (s-vf) grained; moderate sorting; 15% carbonaceous material; light grey, weathering grey; moderately resistant; sharp lower contact.
G26-2	2.1	65.1	Calcareous claystone; c-s; well sorted; finely laminated; 0% carbonaceous material; medium grey, weathering light grey; recessive; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
G27-2	1.6	66.7	Limestone, very fine (s-f) grained; moderate sorting; 0% carbonaceous material; light grey, weathering grey; resistant; sharp lower contact.
G28-2	1.32	68.1	Limestone, aphanitic; c-s; 5% carbonaceous material; medium dark grey, weathering grey; resistant; sharp lower contact.
G28-3	1.32	69.4	Limestone, aphanitic; coquinoid layers; 3% carbonaceous material; medium grey, weathering grey; resistant; gradational lower contact.
G29-1	1.1	70.4	Limestone; grain size of silt (c-vf); poor sorting; 15% carbonaceous material; abundant symmetrical ripple marks; medium grey, weathering brown grey; resistant; gradational lower contact.
G30-1	0.35	75.8	Limestone; grain size of silt; well sorted; 2% carbonaceous material; laminated; ripple marks; medium light grey, weathering grey; recessive; sharp lower contact.
G31-1	2.3	73.1	Limestone; grain size of clay (c-s); well sorted; 2% carbonaceous material; laminated; medium light grey, weathering grey; resistant; sharp lower contact.
G32-1	0.55	73.7	Limestone; grain size of clay; well sorted; some invertebrate fossils; 5% carbonaceous material; medium light grey, weathering grey; resistant; sharp lower contact.
G33-1	1.18	74.8	Limestone; grain size of silt (c-vf); poor sorting; irregular ripple marks; 15% carbonaceous material; medium light grey, weathering grey; resistant; sharp lower contact.
G34-1	2.2	77.1	Limestone; grain size of clay; well sorted; abundant invertebrate fossils; 0% carbonaceous material; medium light grey, weathering grey; moderately resistant; sharp lower contact.

Top of Gladstone Formation

Total thickness of the formation is 77 metres

Total thickness of the Calcareous Member is 14 metres

Beaver Mines Formation

G35-1	0.9	77.9	Claystone; c-s; well sorted; dark grey, weathering the same; recessive; sharp lower contact.
G36-1	0.8	78.7	Siltstone; c-s; well sorted; laminated; ripple marks; dark grey, weathering the same; gradational lower contact.
G37-1	2.4	81.2	Sandstone; medium (f-m) grained; moderate sorting; subrounded (sa-sr) clasts; 0% carbonaceous material; massive; olive grey, weathering green grey; resistant; gradational lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
G38-1	3.1	82.3	Conglomerate; medium sand--12mm; poor sorting; subrounded (sr-r) clasts; 0% carbonaceous material; large trough cross-beds; medium light grey, weathering medium grey; moderately resistant; gradational lower contact.
G39-1	2.4	85.6	Sandstone, fine (f-m) grained; moderate sorting; subrounded (sa-sr) clasts; massive; 0% carbonaceous material; green grey, weathering green grey; moderately resistant; sharp lower contact.
G40-1	1.4	88.1	Sandstone, very fine (s-vf) grained; moderate sorting; angular (va-sa) clasts; 3% carbonaceous material; green grey, weathering green; moderately resistant; sharp lower contact.
G41-1	16.5	104.5	Siltstone; s-vf; moderate sorting; subangular (a-sr) clasts; 5% carbonaceous material; green grey, weathering green; moderately resistant; sharp lower contact.
G42-1	1.0	105.5	Claystone; no sample; mottled red and green; recessive; gradational lower contact.
G43-1	0.6	106.2	Sandstone, very fine (s-f) grained; moderate sorting; subrounded (sa-sr) clasts; green grey, weathering brown grey; moderately resistant; sharp lower contact.
G44-1	0.5	106.6	Siltstone; no sample; green grey, weathering grey; moderately resistant; gradational lower contact.
G45-1	0.4	107.1	Sandstone, very fine (s-f) grained; poor sorting; subangular (a-sr) clasts; 5% carbonaceous material; thins laterally; green grey, weathering light grey; moderately resistant.
G46-1	1.2	108.2	Claystone; c-s; well sorted; 10% carboncaeous material; calcareous concretions; medium grey, weathering brown; recessive; gradational lower contact.
G47-1	0.6	108.8	Siltstone; no sample; calcareous concretions; dark grey; recessive; gradational lower contact.
G48-1	1.3	110.2	Sandstone, very fine (s-vf) grained; moderate sorting; subangular (a-sr) clasts; 0% carbonaceous material; green grey, weathering grey; sharp lower contact.
G49-1	0.4	110.6	Claystone; no sample; grey; recessive; sharp lower contact.
G50-1	0.5	111.1	Sandstone, very fine (s-f) grained; poor sorting; angular (va-sa) clasts; 10% carbonaceous material; green grey, weathering grey; resistant; sharp to erosional lower contact.
G51-1	0.95	111.5	Sandstone, medium (f-m) grained; moderate sorting; subrounded (sa-sr) clasts; 3% carbonaceous material; green grey, weathering green grey; resistant; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
G52-1	0.25	112.3	Sandstone, very fine (s-f) grained; moderate sorting; subangular (a-sr) clasts; 0% carbonaceous material; green grey, weathering green; moderately resistant; gradational lower contact.
G53-1	0.45	112.7	Sandstone, fine (vf-m) grained; moderate sorting; subangular (sa-sr) clasts; 1% carbonaceous material; green grey, weathering green grey; moderately resistant; sharp lower contact.
G54-1	0.2	112.9	Claystone; c-s; moderate sorting; 2% carbonaceous material; dark grey, weathering grey; recessive; gradational lower contact.
G55-1	0.6	113.51	Siltstone; c-vf; poor sorting; subangular (a-sr) clasts; 8% carbonaceous material; green grey, weathering brown grey; moderately resistant; gradational lower contact.
G56-1	0.8	114.3	Sandstone, fine (vf-f) grained; poor sorting; subangular (a-sr) clasts; 8% carbonaceous material; medium dark grey, weathering green grey; moderately resistant; sharp lower contact.
G57-1	0.3	114.6	Sandstone, very fine (s-f) grained; poor sorting; angular (va-sa) clasts; 10% carbonaceous material; medium dark grey, weathering grey; moderately resistant; gradational lower contact.
G58-1	0.5	115.1	Siltstone; c-vf; poor sorting; angular clasts; faint laminations; 8% carbonaceous material; dark green grey, weathering brown grey; moderately resistant; sharp lower contact.
G59-1	1.3	116.4	Claystone; well sorted; plant fragments; dark grey, weathering grey; recessive; gradational lower contact.
G60-1	0.8	117.2	Siltstone; c-s; moderate sorting; angular clasts; 5% carbonaceous material; dark green grey, weathering light grey; recessive.
G61-1	0.9	118.1	Sandstone, very fine (s-vf) grained; poor sorting; subangular (sa-sr) clasts; 5% carbonaceous material; mud clasts; dark green grey, weathering grey; resistant; sharp lower contact.
G62-1	1.2	119.3	Sandstone, fine (vf-m) grained; moderate sorting; subangular (sa-sr) clasts; dark green grey, weathering green grey; moderately resistant; sharp lower contact.
G63-1	0.21	119.5	Claystone; well sorted; dark grey, weathering grey; recessive; sharp lower contact.
G64-1	0.15	121.0	Siltstone; c-s; moderate sorting; 2% carbonaceous material; dark green grey, weathering brown grey; moderately resistant; gradational lower contact.

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Sample Number	Thick-ness (metres)	Position (metres from base)	Description
G65-1	0.2	121.1	Sandstone, very fine (vf-f) grained; poor sorting; angular (va-sa) clasts; 0% carbonaceous material; dark green grey, weathering grey; resistant; sharp to erosional lower contact.
G65-2	1.0	122.2	Sandstone, fine (vf-f) grained; moderate sorting; subangular (sa-sr) clasts; 0% carbonaceous material; dark green grey, weathering grey; resistant; gradational lower contact.
G66-1	0.6	122.8	Sandstone, very fine (vf-f) grained; moderate sorting; subangular (sa-sr) clasts; 3% carbonaceous material; occasional plant remains; dark green grey, weathering brown grey; moderately resistant; sharp lower contact.
G67-1	0.3	123.1	Sandstone, very fine (s-vf) grained; moderate sorting; subrounded (sa-sr) clasts; 2% carbonaceous material; dark green grey, weathering brown grey; moderately resistant; sharp lower contact.
G68-1	0.45	123.5	Claystone; well sorted; dark grey, weathering dark grey; recessive; sharp lower contact.
G69-1	1.3	124.9	Sandstone, fine (vf-f) grained; moderate sorting; subrounded (sa-sr) clasts; 3% carbonaceous material; dark green grey, weathering brown grey; resistant; sharp lower contact.
G70-1	0.3	125.2	Sandstone, very fine (s-vf) grained; poor sorting; subrounded (sa-sr) clasts; 2% carbonaceous material; green grey, weathering grey; moderately resistant; gradational lower contact.
G71-1	0.4	125.6	Siltstone; c-vf; moderate sorting; 1% carbonaceous material; green grey, weathering brown grey; recessive; gradational lower contact.
G72-1	0.9	126.2	Sandstone, very fine (s-vf) grained; well sorted; subangular (sa-sr) clasts; 0% carbonaceous material; mud clasts; occasional plant remains; green grey, weathering green grey; moderately resistant; sharp lower contact.
G73-1	0.35	126.8	Siltstone; c-s; well sorted; laminated; ripple marks; olive grey, weathering brown grey; recessive; sharp lower contact.
	0.6		Covered.
G74-1	0.4	127.8	Same as G73-1.
G75-1	1.4	129.2	Sandstone, very fine (s-vf) grained; moderate sorting; subrounded (sa-sr) clasts; 0% carbonaceous material; small trough cross-beds; olive grey, weathering brown grey; moderately resistant; sharp lower contact.
	0.4		Covered.

Sample Number	Thick- ness (metres)	Position (metres from base)	Description
G76-1	0.2	129.8	Claystone; well sorted; dark grey; recessive.
G77-1	0.3	130.1	Sandstone, very coarse (medium sand--7mm) grained; moderate sorting; subrounded (sa-sr) clasts; occasional plant remains; green grey, weathering green grey; resistant; erosional lower contact.
G78-1	2.0	130.1	Sandstone, medium (f-m) grained; moderate sorting; subrounded (sa-sr) clasts; 5% carbonaceous material; green grey, weathering green grey; abundant plant remains near base; resistant; gradational lower contact.
G78-2	2.0	132.1	Same as G78-1; rare plant remains.
G78-3	2.0	134.1	Same as G78-1; abundant plant remains at base.
G78-4	2.0	136.1	Same as G78-1.
G79-1	1.0	139.1	Sandstone, medium (f-m) grained; well sorted; subrounded (sa-r) clasts; 1% carbonaceous material; light olive grey, weathering brown grey; laminated; resistant; sharp lower contact.
G80-1	2.0	141.1	Sandstone, medium (f-m) grained; moderate sorting; subrounded (a-sr) clasts; 0% carbonaceous material; light olive grey, weathering green grey; resistant; sharp lower contact.
G81-1	2.0	143.1	Sandstone, fine (f-m) grained; moderate sorting; subrounded (sa-sr) clasts; 0% carbonaceous material; green grey, weathering grey; resistant; gradational lower contact.
G82-1	1.0	144.1	Sandstone, fine (vf-f) grained; poor sorting; subangular (sa-sr) clasts; 8% carbonaceous material; abundant plant remains at base; thin bedded; grey gren, weathering brown grey; resistant; gradational lower contact.
G83-1	2.0	146.1	Same as G82-1; no plant remains.
G84-1	2.8	148.9	Sandstone, medium (vf-m) grained; moderate sorting; 0% carbonaceous material; light olive grey, weathering dark grey; resistant; gradational lower contact.
G85-1	2.3	151.2	Same as G85-1.
G86-1	0.3	151.5	Claystone; c-s; well sorted; green grey, weathering dark grey; abundant plant remains; recessive; sharp lower contact.
G87-1	1.2	152.7	Siltstone; c-s; moderate sorting; subangular (a-sa) clasts; green grey, weathering brown grey; moderately resistant; gradational lower contact.
G88-1	1.05	153.7	Sandstone, very fine (s-f) grained; poor sorting; subangular (a-sa) clasts; cross-bedded; 0% carbonaceous material; olive grey, weathering light grey; moderately resistant; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
G89-1	3.0	156.7	Siltstone; c-s; poor sorting; subangular (a-sa) clasts; minor fault; laminated; dark green grey, weathering dark grey; recessive; sharp lower contact.
G89-2	2.0	158.7	Siltstone; c-vf; moderate sorting; subangular (sa-sr) clasts; laminated; dark green grey, weathering dark grey; plant remains; resistant.
G90-1	0.48	159.3	Claystone; c-s; well sorted; dark grey, weathering dark grey; recessive; gradational lower contact.
G91-1	1.0	159.4	Siltstone; c-s; moderate sorting; laminated; green grey, weathering dark grey; moderately resistant; gradational lower contact.
G91-2	3.3	163.5	Same as G91-1.
G91-3	2.1	165.7	Same as G91-1.
G91-4	1.0	166.7	Sandstone, very fine (v-f) grained; moderate sorting; subangular (sa-sr) clasts; 3% carbonaceous material; green grey, weathering dark grey; moderately resistant; gradational lower contact.
	2.2		Covered.
G92-1	0.6	170.3	Claystone; well sorted; green grey, weathering dark grey; recessive.
G93-1	0.65	170.9	Sandstone, very fine (s-f) grained; poor sorting; subrounded (sa-sr)clasts; 2% carbonaceous material; green grey, weathering green grey; resistant; erosional lower contact.
G94-1	0.15	171.1	Claystone; c-vf; poor sorting; green grey, weathering green; recessive; sharp lower contact.
G95-1	0.4	171.5	Sandstone; fine (vf-f) grained; poor sorting; subangular (a-sr) clasts; 3% carbonaceous material; green grey, weathering green grey; moderately resistant; gradational lower contact.
	3.0		Covered.
G96-1	1.33	174.8	Sandstone, very fine (s-vf) grained; poor sorting; subangular (sa-r) clasts; 2% carbonaceous material; large trough cross-beds; green grey, weathering green; moderately resistant; gradational lower contact.
G97-1	4.0	178.8	Claystone; c-s; moderate sorting; plant remains; dark grey, weathering grey; recessive; sharp lower contact.
G98-1	0.23	179.1	Sandstone, fine (vf-f) grained; moderate sorting; subrounded (sa-sr) clasts; mud clasts; green grey, weathering brown grey; moderately resistant; sharp lower contact.
G99-1	0.52	179.5	Sandstone, medium (f-m) grained; poor sorting; subangular (sa-sr) clasts; 0% carbonaceous material; green grey, weathering green; moderately resistant; gradational lower contact.

Sample Number	Thickness (metres)	Position (metres from base)	Description
G100-1	0.76	180.3	Sandstone; medium (vf-m) grained; moderate sorting; subrounded (sa-sr) clasts; 2% carbonaceous material; green grey, weathering grey; moderately resistant; gradational lower contact.
G101-1	0.64	180.9	Sandstone, very fine (s-f) grained; poor sorting; subangular (sa-sr) clasts; 0% carbonaceous material; green grey, weathering grey; moderately resistant; gradational lower contact.
G102-1	0.98	181.9	Siltstone; c-vf; poor sorting; medium grey, weathering dark grey; recessive; sharp lower contact.
G103-1	3.07	184.9	Sandstone, medium (f-m) grained; poor sorting; subangular (sa-sr) clasts; 0% carbonaceous material; abundant large trough cross-beds; olive grey, weathering green grey; resistant; sharp lower contact.
G104-1	0.35	185.3	Claystone; c-s; well sorted; medium grey, weathering grey; recessive; sharp lower contact.
G105-1	0.65	185.9	Siltstone; c-vf; moderate sorting; laminated; green grey, weathering grey; moderately resistant; gradational lower contact.
G106-1	0.44	186.3	Claystone; well sorted; laminated; medium grey, weathering grey; recessive; sharp lower contact.
G107-1	0.64	186.9	Sandstone, fine (s-f) grained; poor sorting; subrounded (sa-r) clasts; 2% carbonaceous material; green grey, weathering brown grey; resistant; sharp lower contact.
G108-1	0.63	187.6	Claystone; c-s; moderate sorting; laminations; green grey, weathering brown grey; recessive; sharp lower contact.
G109-1	0.85	188.4	Sandstone, fine (s-f) grained; poor sorting; subangular (sa-sr) clasts; 0% carbonaceous material; green grey, weathering grey; resistant; sharp lower contact.
G110-1	1.55	189.9	Claystone; well sorted; green grey, weathering dark grey; moderately resistant; gradational lower contact.
G111-1	0.77	190.7	Siltstone; c-vf; moderate sorting; subangular (sa-sr) clasts; 0% carbonaceous material; green grey, weathering brown grey; moderately resistant; gradational lower contact.
G112-1	0.55	191.2	Claystone; no sample; dark grey; recessive; sharp lower contact.
G113-1	1.72	193.1	Sandstone, very fine (s-vf); poor sorting; subangular (sa-sr) clasts; 0% carbonaceous material; green grey, weathering green; resistant; sharp lower contact.

Sample Number	Thick- ness (metres)	Position (metres from base)	Description
G114-1	0.43	193.4	Claystone; well sorted; dark grey, weathering black; recessive; sharp lower contact.
G115-1	1.14	194.6	Siltstone; c-s; well sorted; angular (a-sa) clasts; ripple marks; green grey, weathering medium grey; moderately resistant; gradational lower contact.
G116-1	0.4	195.0	Claystone; well sorted; dark green grey, weathering green; recessive; sharp lower contact.
G117-1	0.33	195.3	Siltstone; s-vf; moderate sorting; subangular (a-sr) clasts; 0% carbonaceous material; dark green grey, weathering green grey; recessive; gradational lower contact.
G118-1	0.7	196.0	Sandstone; very fine (s-vf) grained; poor sorting; subangular (a-sr) clasts; 0% carbonaceous material; green grey, weathering green; moderately resistant; gradational lower contact.
G119-1	1.08	197.1	Claystone; well sorted; dark green grey, weathering brown grey; moderately resistant; sharp lower contact.
G120-1	2.0	201.1	Sandstone, fine (vf-f) grained; poor sorting; angular (a-sa) clasts; 0% carbonaceous material; green grey, weathering green grey; moderately resistant; sharp lower contact.
	3.5		Covered.
G121-1	1.6	204.2	Claystone; c-s; moderate sorting; calcareous concretions; green grey, weathering brown grey; moderately resistant.
G122-1	3.35	207.5	Claystone; well sorted; green grey, weathering brown; recessive; gradational lower contact.
G123-1	0.64	208.2	Siltstone; c-s; moderate sorting; green grey, weathering grey; moderately resistant; gradational lower contact.
G124-1	0.25	208.5	Claystone; well sorted; green grey, weathering grey; moderately resistant; gradational lower contact.
G125-1	1.0	209.4	Siltstone; c-s; moderate sorting; 1% carbonaceous material; green grey, weathering brown; moderately resistant; gradational lower contact.
G126-1	0.25	209.7	Claystone; no sample; same as G124-1.
G127-1	0.6	210.3	Sandstone, very fine (c-vf) grained; moderate sorting; subangular (a-sa) clasts; green grey, weathering grey; moderately resistant; sharp lower contact.
G128-1	0.6	210.9	Claystone; c-s; well sorted; ripple marks; laminations; green grey, weathering grey; recessive; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
G129-1	0.45	211.4	Siltstone; c-vf; moderate sorting; angular (a-sr) clasts; green grey, weathering grey; recessive; gradational lower contact.
G130-1	0.9	212.3	Sandstone, medium (f-m) grained; poor sorting; subangular (sa-sr) clasts; 0% carbonaceous material; green grey, weathering brown grey; moderately resistant; gradational lower contact.
G131-1	1.4	213.6	Claystone; c-s; moderate sorting; green grey, weathering dark brown; recessive; sharp lower contact.
G132-1	4.0	217.6	Sandstone, medium (f-m) grained; moderate sorting; subangular (sa-sr) clasts; 0% carbonaceous material; green grey, weathering grey; erosional at base; resistant.
G132-2	2.0	219.6	Sandstone, very fine (s-f) grained; poor sorting; subangular (a-sr) clasts; 0% carbonaceous material; horizontally bedded; green grey, weathering brown grey; resistant; gradational lower contact.
G132-3	2.0	221.6	Sandstone, medium (f-m) grained; poor sorting; subangular (a-sr) clasts; 0% carbonaceous material; horizontally bedded; green grey, weathering brown grey; resistant; gradational lower contact.
G132-4	2.0	223.6	Sandstone, fine (vf-f) grained; moderate sorting; subangular (a-sr) clasts; horizontally bedded; 0% carbonaceous material; green grey, weathering brown grey; resistant; gradational lower contact.
G132-5	2.0	225.6	Sandstone, medium (f-m) grained; poor sorting; subrounded (sa-r) clasts; 0% carbonaceous material; horizontally bedded; green grey, weathering brown grey; resistant; gradational lower contact.
G132-6	2.0	227.6	Same as G132-5.
G133-1	2.5	230.6	Sandstone, very fine (s-f) grained; poor sorting; subangular (a-sr) clasts; 0% carbonaceous material; thin bedded; green grey, weathering brown; resistant; gradational lower contact.
G134-1	1.7	232.3	Sandstone, medium (vf-m) grained; poor sorting; subrounded (sa-sr) clasts; 0% carbonaceous material; green grey, weathering grey; resistant; sharp lower contact.
G135-1	1.0	233.4	Claystone; c-s; well sorted; medium grey, weathering dark grey; recessive; sharp lower contact.
G136-1	2.0	235.4	Sandstone, medium (f-m) grained; poor sorting; subangular (a-sr) clasts; 0% carbonaceous material; green grey, weathering green grey; resistant; sharp lower contact.

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Sample Number	Thick-ness (metres)	Position (metres from base)	Description
G136-2	2.0	237.4	Same as G136-1.
G136-3	4.0	241.4	Sandstone, fine (vf-m) grained; poor sorting; subangular (a-sr) clasts; 0% carbonaceous material; green grey, weathering green grey; resistant; gradational lower contact.
G137-1	1.5	242.9	Claystone; well sorted; medium grey, weathering dark grey; recessive.
	2.0		Covered.
G138-1	2.1	246.9	Sandstone, fine (vf-f) grained; moderate sorting; subangular (sa-sr) clasts; 0% carbonaceous material; moderately resistant.
G139-1	0.4	247.4	Claystone; well sorted; medium grey, weathering grey; recessive; sharp lower contact.
G140-1	0.52	247.8	Sandstone, fine (vf-f) grained; moderate sorting; subangular (sa-sr) clasts; thin bedded; green grey, weathering grey; moderately resistant; sharp lower contact.
G141-1	2.5	250.4	Sandstone, very fine (s-vf) grained; poor sorting; subangular (a-sa) clasts; green grey, weathering dark grey; recessive; sharp lower contact.
G142-1	5.2	255.6	Claystone; c-s; moderate sorting; mottled red and green; recessive; sharp lower contact.
G143-1	0.3	265.5	Siltstone; c-vf; poor sorting; angular (va-sa) clasts; 0% carbonaceous material; green grey, weathering green grey; recessive; sharp lower contact.
G144-1	5.0	261.5	Claystone; c-s; moderate sorting; mottled red and green; recessive; sheared lower contact.
G145-1	0.8	262.3	Sandstone, very fine (s-vf) grained; poor sorting; subangular (a-sr) clasts; green grey, weathering grey; recessive; gradational lower contact.
G146-1	3.0	265.7	Claystone; c-s; moderate sorting; banded red and green; calcareous concretions; recessive; sheared lower contact.
G147-1	1.7	266.9	Siltstone; c-vf; poor sorting; calcareous concretions; green grey, weathering grey; recessive; gradational lower contact.
G148-1	2.0	268.9	Claystone; c-s; moderate sorting; calcareous concretions; mottled red and green; recessive.
G149-1	0.25	269.2	Sandstone, fine (c-m) grained; poor sorting; subangular (a-sr) clasts; 0% carbonaceous material; green grey, weathering green grey; recessive; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
G150-1	1.1		Claystone; c-s; moderate sorting; calcareous concretions; mottled and banded red and green; moderately resistant; gradational lower contact.
G151-1	0.7	280.0	Claystone; c-s; moderate sorting; green grey, weathering grey; moderately resistant; gradational lower contact.
			Top of the section on Gladstone Creek. Section continues on Mill Creek
	10		Covered
M117-1	0.9	291.5	Claystone; c-s; well sorted; dark green grey, weathering grey; recessive.
	0.3		Covered.
M116-1	0.6	292.4	Siltstone; c-s; moderate sorting; dark green grey, weathering grey; recessive.
	0.6		Covered.
M115-1	0.45	293.0	Sandstone, fine (vf-m) grained; moderate sorting; angular (a-sa) clasts; 0% carbonaceous material; green grey, weathering dark green; moderately resistant.
	3.0		Covered.
M114-1	1.15	297.6	Sandstone, very fine (s-vf) grained; poor sorting; angular (a-sa) clasts; 0% carbonaceous material; green grey, weathering grey; moderately resistant.
	1.9		Covered.
M113-1	1.1	300.6	Claystone; c-s; moderate sorting; dark green grey, weathering grey; moderately resistant.
M112-1	0.55	340.7	Claystone; well sorted; mottled red and green; moderately resistant; sharp lower contact.
	4.0		Covered.
M111-1	1.5	306.7	Sandstone, fine (vf-m) grained; moderate sorting; subangular (a-sr) clasts; 0% carbonaceous material; green grey, weathering green grey; resistant.
	3.0		Covered.
M110-1	1.4	311.1	Siltstone; c-s; moderate sorting; angular (va-sa) clasts; olive grey, weathering green; moderately resistant.
	3.0	-	Covered.
M109-1	1.0	315.1	Claystone; well sorted; dark green grey, weathering green; recessive.
M108-1	0.9	315.9	Sandstone, medium (f-m) grained; moderate sorting; subrounded (sa-sr) clasts; 0% carbonaceous material; green grey, weathering green grey; resistant; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
M107-1	0.28	316.3	Claystone; well sorted; dark green grey, weathering grey; recessive; sharp lower contact.
M106-1	1.0	317.3	Sandstone, very fine (s-vf) grained; poor sorting; angular (a-sa) clasts; 0% carbonaceous material; olive grey, weathering grey; moderately resistant; gradational lower contact.
M105-1	1.8	319.1	Claystone; well sorted; dark green grey, weathering grey; recessive; gradational lower contact.
M104-1	0.7	319.8	Sandstone, fine (s-f) grained; moderate sorting; angular (a-sr) clasts; rare plant remains; 0% carbonaceous material; green grey, weathering grey; resistant; sharp lower contact.
M103-1	2.0	321.7	Sandstone, very fine (s-vf) grained; moderate sorting; 3% carbonaceous material; green grey, weathering brown grey; recessive; sharp lower contact.
M102-1	1.65	323.4	Claystone; c-s; moderate sorting; siltstone in places (M102-2); dark green grey, weathering grey; recessive; sharp lower contact.
M101-1	1.25	324.7	Sandstone, very fine (c-vf) grained; poor sorting; angular (va-sa) clasts; 0% carbonaceous material; dark green grey, weathering grey; moderately resistant; sharp lower contact.
M100-1	0.7	325.3	Sandstone, very fine (vf-m) grained; poor sorting; subangular (sa-sr) clasts; 0% carbonaceous material; green grey, weathering green grey; resistant; sharp lower contact.
	10.0		Covered.
M99-1	2.4	337.8	Sandstone, medium (f-m) grained; poor sorting; angular (a-sa) clasts; 0% carbonaceous material; green grey, weathering green grey; resistant.
	6.0		Covered.
M98-1	2.7	346.5	Siltstone; c-vf; poor sorting; green grey, weathering grey; recessive.
M97-1	4.3	350.8	Claystone; c-s; well sorted; green grey, weathering grey; recessive; gradational lower contact.
M96-1	0.15	350.9	Claystone; well sorted; bioturbated; olive grey, weathering grey; resistant; sharp lower contact.
M95-1	0.25	351.2	Same as M96-1.
M94-1	2.0	353.2	Siltstone; c-s; moderate sorting; 3% carbonaceous material; green grey, weathering grey; resistant; sharp lower contact.
M93-1	1.5	354.1	Claystone; c-s; well sorted; green grey, weathering grey; moderately resistant; gradational lower contact.

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Sample Number	Thick-ness (metres)	Position (metres from base)	Description
M92-1	1.0	355.6	Siltstone; c-s; moderate sorting; 0% carbonaceous material; green grey, weathering grey; recessive; sharp lower contact.
M91-1	0.58	356.2	Sandstone, fine (vf-m) grained; poor sorting; subangular (sa-sr) clasts; 0% carbonaceous material; green grey, weathering dark green; moderately resistant; sharp lower contact.
M90-1	1.1	357.3	Claystone; well sorted; dark green grey, weathering green grey; recessive; sharp lower contact.
M89-1	0.9	358.2	Sandstone, fine (vf-f) grained; poor sorting; subrounded (sa-sr) clasts; 0% carbonaceous material; resistant; sharp lower contact.
M88-1	0.3	385.5	Claystone; well sorted; green, weathering green grey; recessive; sharp lower contact.
M87-1	0.6	359.3	Siltstone; c-s; moderate sorting; laminated; dark green grey, weathering dark green; resistant; sharp lower contact.
M86-1	0.8	359.9	Claystone; c-s; moderate sorting; yellow green, weathering light green; moderately resistant; sharp lower contact.
M85-1	1.05	360.9	Siltstone; c-s; poor sorting; thin bedded; bioturbated; olive grey, weathering grey; recessive; sharp lower contact.
M84-1	2.0	362.9	Claystone; c-s; moderate sorting; yellow green, weathering green; recessive; sharp lower contact.
M83-1	0.66	363.6	Limestone, very fine grained; abundant broken invertebrate fossils; medium grey, weathering grey; moderately resistant; gradational lower contact.
M82-1	0.13	363.7	Limestone; aphonitic; rare invertebrate fossils; fissile; medium grey, weathering grey; recessive; sharp lower contact.
M81-1	0.23	364.0	Limestone; very fine grained; invertebrate fossils; medium grey, weathering grey; 2% carbonaceous material; recessive; sharp lower contact.
M80-1	5.3	369.3	Claystone; c-s; moderate sorting; yellow green, weathering light green; recessive; sharp lower contact.
	1.0	-	Covered.
M79-1	1.7	372.0	Siltstone; c-s; moderate sorting; olive grey, weathering green grey; moderately resistant; sharp lower contact.

Top of the Beaver Mines Formation

Total thickness of formation is 298 metres

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
			Gladstone Formation
M78-1	3.6	375.0	Sandstone, very fine (s-vf) grained; poor sorting; subangular (a-sa) clasts; 8% carbonaceous material; invertebrate fossils (eroded from Beaver Mines?); green grey, weathering grey; recessive; sharp lower contact.
M77-2	2.0	377.6	Sandstone, fine (vf-m) grained; moderate sorting; angular (va-sr) clasts; 2% carbonaceous material; light olive grey, weathering buff; resistant; sharp lower contact.
M77-1	2.0	379.6	Same as M77-2.
M76-1	0.88	380.5	Sandstone, fine (vf-f) grained; moderate sorting; angular (a-sa) clasts; 12% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.
	0.8		Covered.
M75-1	2.0	383.3	Claystone; well sorted; papery; medium grey, weathering grey; recessive.
M74-1	0.55	383.8	Siltstone; moderate sorting; angular (va-sa) clasts; 12% carbonaceous material; medium grey, weathering grey; moderately resistant; sharp lower contact.
M73-1	0.31	384.1	Claystone; moderate sorting; medium grey, weathering grey; recessive; papery; sharp lower contact.
M72-1	0.75	384.9	Siltstone; c-vf; moderate sorting; angular (va-sa) clasts; bioturbated; 15% carbonaceous material; medium grey, weathering grey; recessive; gradational lower contact.
M71-1	1.0	385.9	Sandstone, medium (f-crs) grained; moderate sorting; subrounded (sa-sr) clasts; medium light grey, weathering grey; moderately resistant; sharp lower contact.
M70-4	1.45	387.3	Sandstone, very fine (s-vf) grained; moderate sorting; 8% carbonaceous material; bioturbated; ripple marks; medium grey, weathering brown grey; moderately resistant.
M70-3	2.0	389.3	Same as M70-4.
M70-2	2.0	391.3	Same as M70-4.
M70-1	2.0	393.3	Same as M70-4; sharp lower contact.
M69-5	1.5	394.8	Sandstone, medium (f-m) grained; moderate sorting; subangular clasts; large scale trough cross-beds; 0% carbonaceous material; medium grey, weathering grey; resistant; sharp lower contact.
M69-4	2.0	396.8	Same as M69-5.
M69-3	3.0	399.8	Sandstone, medium (vf-m) grained; moderate sorting; subrounded (sa-sr) clasts; large trough cross-beds; 3% carbonaceous material; light olive grey, weathering grey; resistant; gradational lower contact.

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Sample Number	Thickness (metres)	Position (metres from base)	Description
M69-2	2.0	401.8	Sandstone, medium (f-m) grained; well sorted; subangular (a-sr) clasts; 5% carbonaceous material; large trough cross-beds; light olive grey, weathering grey; resistant; gradational lower contact.
M69-1	2.0	403.8	Same as M69-2.
M68-3	0.5	403.9	Sandstone, very fine (s-vf) grained; moderate sorting; subangular (sa-sr) clasts; 12% carbonaceous material; asymmetrical ripple marks; occasional plant remains; medium grey, weathering grey; resistant; sharp lower contact.
M68-2	1.5	405.9	Sandstone, fine (vf-f) grained; well sorted; subangular (sa-sr) clasts; 5% carbonaceous material; asymmetrical ripple marks; occasional plant remains; medium grey, weathering grey; resistant; gradational lower contact.
M68-1	2.0	407.8	Same as M68-2.
M67-1	2.0	408.8	Sandstone, medium (f-crs) grained; well sorted; subangular (a-sa) clasts; 0% carbonaceous material; large cross-beds; light olive grey, weathering grey; resistant; sharp lower contact.
M66-4	2.0	409.8	Same as M67-1.
M66-3	2.0	411.8	Sandstone, fine (f-m) grained; well sorted; subangular (a-sr) clasts; 3% carbonaceous material; large cross-beds; light olive grey, weathering grey; resistant; gradational lower contact.
M66-2	3.5	415.3	Same as M66-3.
M66-1	0.5	417.8	Same as M66-3.
M65-1	2.0	419.8	Sandstone, fine (vf-m) grained; moderate sorting; subangular (a-sr) clasts; 1% carbonaceous material; medium grey, weathering grey; resistant; gradational lower contact.
M64-1	3.0	422.8	Siltstone; moderate sorting; angular (va-sa) clasts; 5% carbonaceous material; green grey, weathering brown green; moderately resistant; sharp lower contact.
			Samples M63-1 to M57-1 inclusively not used. Portion of section repeated by minor faulting.
M56-1	0.3	423.1	Sandstone, fine (vf-m) grained; poor sorting; subangular (a-sr) clasts; 0% carbonaceous material; dark green grey, weathering green grey; recessive; sharp lower contact.
M55-1	0.3	423.4	Siltstone; c-f; poor sorting; green grey, weathering green; recessive; gradational lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
M54-1	2.2	425.6	Sandstone, fine (vf-f) grained; poor sorting; subangular (sa-sr) clasts; 0% carbonaceous material; large trough cross-beds; medium grey, weathering green grey; resistant; sharp lower contact.
M53-1	0.08	425.7	Claystone; well sorted; occasional plant remains; dark grey, rusty weathering; recessive; sharp lower contact.
M52-1	1.65	427.3	Sandstone, fine (vf-m) grained; moderate sorting; angular (va-sa) clasts; 2% carbonaceous material; cross-beds; medium grey, weathering grey; resistant; sharp lower contact.
M51-1	3.30	430.6	Sandstone, very fine (s-f) grained; moderate sorting; subangular (a-sr) clasts; 1% carbonaceous material; thin bedded; green grey, weathering green; recessive; sharp lower contact.
M50-1	1.45	432.1	Claystone; well sorted; 1% carbonaceous material; dark grey, weathering grey; recessive; gradational lower contact.
M49-1	1.01	433.1	Same as M50-1.
M48-1	0.52	433.6	Sandstone, very fine (s-vf) grained; well sorted; angular (a-sa) clasts; 15% carbonaceous material; cross-beds; medium grey, weathering grey; resistant; sharp lower contact.
M47-1	1.27	434.9	Claystone; well sorted; calcareous concretions; medium grey, weathering grey; recessive; sharp lower contact.
M46-1	0.63	435.5	Sandstone, very fine (s-vf) grained; poor sorting; subangular (sa-sr) clasts; 10% carbonaceous material; medium dark grey, weathering grey; resistant; sharp lower contact.
M45-1	0.3	435.8	Claystone; well sorted; dark grey, weathering grey; recessive; sharp lower contact.
M44-1	0.8	436.6	Claystone; moderate sorting; medium grey, weathering grey; moderately resistant; sharp lower contact.
M43-1	1.7	438.2	Sandstone, fine (vf-m) grained; subangular (a-sr) clasts; 1% carbonaceous material; medium grey, weathering brown grey; moderately resistant; sharp lower contact.
			No Unit M42-1.
M41-1	0.72	439.0	Claystone; well sorted; thinly bedded; medium grey, weathering grey; moderately resistant; sharp lower contact.
M40-1	3.6	442.6	Sandstone, very fine (vf-f) grained; poor sorting; subangular (a-sa) clasts; perhaps tuffaceous in part; medium grey, weathering grey; resistant; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
M39-1	0.85	443.5	Volcanic tuff; dark grey; very fine grained; sharp lower contact.
M38-1	0.22	443.7	Claystone; no sample; green; recessive; sharp lower contact.
M37-1	0.6	444.3	Sandstone, very fine grained; no sample; dark grey; resistant; gradational lower contact.
M36-1	1.11	445.4	Claystone; well sorted; dark grey, weathering grey; splintery; recessive; gradational lower contact.
M35-1	1.7	447.1	Sandstone, fine (vf-m) grained; poor sorting; subangular (sa-sr) clasts; medium grey, weathering grey; resistant; sharp lower contact with local channeling.
M34-1	1.3	448.4	Siltstone; c-vf; moderate sorting; angular (va-sa) clasts; thin bedded; medium grey, weathering grey; resistant; sharp lower contact.
M33-1	6.2	454.6	Sequence of sandstone, claystone, and tuff; inaccessible.
M32-1	0.18	454.8	Claystone; no sample; pale green; recessive; sharp lower contact.
M31-1	2.1	456.9	Siltstone; no sample; dark grey; recessive; sharp lower contact.
M30-1	3.3	460.2	Sandstone, very fine (s-f) grained; moderate sorting; subangular (a-sa) clasts; 0% carbonaceous material; thin bedded; medium grey, weathering grey; resistant.
M29-1	1.0	461.2	Siltstone; no sample; dark green; recessive; sharp lower contact.
M28-1	3.0	464.2	Claystone; well sorted; mottled red and green; recessive.
			Base of Crowsnest Member
M27-1	9.0	473.2	Tuff, fine grained; dark grey to maroon; resistant; sharp lower contact.
M26-1	1.4	474.6	Claystone; dark grey; hackly; moderately resistant; sharp lower contact.
M25-1	3.5	478.1	Tuffaceous claystone and very fine grained tuff; dark grey; occasional plant remains; recessive; sharp lower contact.
M24-1	5.6	483.7	Sandstone or tuff, very fine grained; dark green, weathering green grey; faulted lower contacted.
M23-1	14.0	497.7	Siltstone, tuffaceous; plant remains 6 metres above base; grey to green; moderately resistant; sharp lower contact.
M22-1	1.5	499.2	Tuff; fedlspathic, fine grained; sharp lower contact.

Sample Number	Thickness (metres)	Position (metres from base)	Description
	8.0		Covered.
M21-1	2.3	509.5	Tuff, very fine grained; medium green; moderately resistant.
M20-1	1.42	510.9	Siltstone, tuffaceous; grey; moderately resistant; sharp lower contact.
M19-1	0.45	511.4	Tuff, coarse grained; lithic; feldspathic; dark green; resistant; sharp lower contact.
M18-1	4.74	516.1	Siltstone; grey; moderately resistant; sharp lower contact.
M17-1	2.8	518.9	Siltstone; mottled red and green; recessive; sharp lower contact.
M16-1	1.3	520.2	Siltstone; grey; sharp lower contact.
M15-1	0.9	521.1	Siltstone, tuffaceous; green; recessive; sharp lower contact.
M14-1	0.97	522.1	Claystone, tuffaceous; red and green; recessive; sharp lower contact.
M13-1	8.0	5301.	Tuffs to pebble-sized agglomerates; feldspathic; green; crudely bedded; minor faulting; moderately resistant; sharp lower contact.
	6.0		Covered.
M12-1	1.7	537.8	Tuff; green; feldspathic.
	10.0		Covered.
M11-1	0.6	548.4	Tuff; feldspathic; pale green; moderately resistant.
M10-1	0.7	549.1	Tuff, medium grained; crystalline; dark green; moderately resistant; sharp lower contact.
M9-1	0.4	549.8	Claystone, tuffaceous; pale green; recessive; sharp lower contact.
M8-1	24.0	573.48	Tuff; feldspathic; lithic; volcanic bomb; pale green; moderately resistant; sharp lower contact.
M7-1	1.3	574.8	Claystone; black, rusty weathering; moderately resistant; sharp lower contact.
M6-1	3.7	578.5	Tuff; very fine grained to pebble agglomerate; feldspathic; green; sharp lower contact.
M5-1	3.5	581.9	Siltstone, tuffaceous; recessive; sharp lower contact.
M4-1	1.53	583.5	Claystone; pale green; recessive; sharp lower contact.
M3-1	1.2	584.7	Agglomerate; green; moderately resistant; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
M2-1	1.8	586.5	Tuff, feldspathic; thin bedded; small cross-beds at base; resistant; gradational lower contact.
	2.7		Covered.

Top of Mill Creek Formation

Total thickness of formation is 215 metres

Total thickness of Blairmore Group is 290 metres

Blackstone Formation

Hig[illegible] contorted and splintered black shales

SHEEP RIVER MEASURED SECTION

Kootenay Formation

Interbedded quartzose sandstone carbonaceous shales

Gladstone Formation

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S1-1	1.1	0.6	Conglomerate; pebble (2.25cm); moderate sorting; subrounded (sa-sr) clasts; 20% dark minerals, 3% carbonaceous material; rare plant remains; brown, weathering rusty; fines upward; resistant; erosional lower contact.
S2-1	0.1	1.2	Sandstone, medium (f-cr) grained; well sorted; subangular (sa-sr) clasts; 25% dark minerals, 7% carbonaceous material; grey brown, weathering grey; resistant; sharp lower contact.
S3-1	1.2	2.5	Conglomerate, pebble (2cm); poor sorting; rounded (sa-r) clasts; 40% dark minerals, 8% carbonaceous material; medium grey, weathering grey; resistant; sharp lower contact.
S4-1	0.9	3.4	Conglomerate, pebble (1cm); well sorted; rounded (sa-r) clasts; 40% dark minerals, 10% carbonaceous material; medium grey, weathering grey; resistant; gradational lower contact.
S5-1	0.8	4.4	Conglomerate, pebble (0.5cm); moderate sorting; subrounded (sa-r) clasts; 40% dark minerals, 10% carbonaceous material; medium grey, weathering brown; resistant; sharp lower contact.
S6-1	0.85	5.3	Sandstone; medium (f-cr) grained; well sorted; subangular (a-sr) clasts; 30% dark minerals, 8% carbonaceous material; 1cm laminations; pebbly lenses; dark grey, weathering grey; resistant; erosional lower contact.
S7-1	0.3	5.6	Sandstone, very fine (s-f) grained; moderate sorting; subrounded (sa-sr) clasts; 10% dark minerals, 5% carbonaceous material; dark grey, weathering grey; moderately resistant; sharp lower contact.
S8-1	0.5	6.1	Siltstone, (c-s); moderate sorting; abundant plant remains; moderately resistant; gradational lower contact.
S9-1	1.0	7.1	Siltstone, (c-vf); moderate sorting; 0% carbonaceous material; dark grey, weathering grey; recessive; gradational lower contact.
S10-1	0.7	7.75	Sandstone, very fine (c-f) grained; poor sorting; 3% carbonaceous material; mud clasts; dark grey, weathering grey; resistant; sharp lower contact.

Sample Number	Thickness (metres)	Position (metres from base)	Description
S11-1	0.9	8.5	Siltstone; c-vf; moderate sorting; subangular (sa-sr) clasts; 5% dark minerals, 2% carbonaceous material; medium grey, weathering grey; resistant; sharp lower contact.
S12-1	2.4	11.0	Claystone; c-s; moderate sorting; 0% carbonaceous material; bioturbated; medium grey, weathering grey; recessive; sharp lower contact.
S13-1	1.0	12.0	Sandstone, very fine grained; well sorted; angular (a-sr) clasts; 2% dark minerals, 0% carbonaceous material; light grey, weathering bro[illegible] resistant; sharp lower contact.
S14-1	0.48	12.7	Conglomerate, pebble (1.25cm); well sorted; subangular (a-sr) clasts; 20% dark minerals, 8% carbonaceous material; medium grey, weathering rusty; moderately resistant; sharp lower contact.
S15-1	1.4	14.0	Siltstone; moderate sorting; 2% dark minerals, 0% carbonaceous material; light grey, weathering grey, resistant; sharp lower contact.
S16-1	2.7	16.4	Siltstone; c-s; well sorted; 0% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.
S17-1	2.0	16.85	Sandstone, fine (vf-f) grained; well sorted; subrounded (sa-sr) clasts; 15% dark minerals, 5% carbonaceous material; small tangential cross-beds; occasional plant remains; light grey, weathering grey; resistant; sharp lower contact.
S17-2	1.4	18.85	Sandstone, fine (vf-f) grained; well sorted; subrounded (sa-sr) clasts; 4% dark minerals, 1% carbonaceous material, light grey; weathering grey; resistant; gradational lower contact.
S18-1	1.7	21.5	Claystone; c-s; moderate sorting; 0% carbonaceous material; algal balls; medium grey, weathering grey; recessive; sharp lower contact.
S19-1	1.0	22.6	Sandstone, very fine grained; well sorted; subangular (a-sa) clasts; 1% dark minerals, 1% carbonaceous material; light grey, weathering grey; resistant; sharp lower contact.
S20-1	0.1	23.03	Sandstone, very fine (s-vf); well sorted; subangular (sa-sr) clasts; 2% dark minerals, 0% carbonaceous material; small tangential cross-beds; medium grey, weathering grey; moderately resistant; sharp lower contact.
S21-1	1.0	23.9	Siltstone; c-vf; moderate sorting; subrounded (sa-sr) clasts; 0% carbonaceous material; bioturbated; medium grey, weathering grey; resistant; sharp lower contact.
S22-1	0.2	24.0	Sandstone, very fine (s-f) grained; poor sorting; subangular (a-sr) clasts; 2% dark minerals, 0% carbonaceous material; medium grey, weathering grey; resistant; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S23-1	0.55	24.7	Siltstone; moderate sorting; 3% dark minerals, 2% carbonaceous material; large tangenial cross-beds; light grey, weathering grey; resistant; sharp lower contact.
S24-1	2.0	24.5	Claystone, c-s; moderate sorting; 0% carbonaceous material; dark grey, weathering grey; recessive; sharp lower contact.
S25-1	1.2	26.1	Siltstone; moderate sorting; bioturbated; light grey, weathering grey; sharp lower contact; 3% dark minerals, 1% carbonaceous material.
S26-1	1.0	27.2	Siltstone; c-vf; poor sorting; 1% dark minerals, 0% carbonaceous material; bioturbated; light grey, weathering grey; resistant; sharp lower contact.
S26-2	2.7	28.2	Siltstone; moderate sorting; 0% dark minerals, 0% carbonaceous material; light grey, weathering grey; resistant; gradational lower contact.
S27-1	0.7	30.4	Siltstone, c-vf; poor sorting; 0% dark minerals, 0% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.
S28-1	1.3	31.5	Siltstone, c-vf; poor sorting; 1% carbonaceous material; medium grey, weathering grey; moderatly resistant; sharp lower contact.
S29-1	0.3	32.1	Claystone; c-s; moderate sorting; 2% carbonaceous material; dark grey, weathering grey; moderately resistant; sharp lower contact.
S30-1	1.5	33.4	Siltstone; moderate sorting; 2% dark minerals, 0% carbonaceous material; asymmetrical ripples; light grey, weathering grey; resistant; sharp lower contact.
S31-1	0.6	34.1	Sandstone, very fine (c-vf) grained; subangular (a-sr) clasts; poor sorting; 5% dark minerals, 2% carbonaceous material; medium grey, weathering grey; moderately resistant; gradational lower contact.
S32-1	0.6	34.6	Claystone; c-s; well sorted; 0% dark minerals, 0% carbonaceous material; light grey, weathering grey; recessive; sharp lower contact.
S33-1	0.25	35.1	Siltstone; c-vf; poor sorting; 1% dark minerals, 1% carbonaceous material; light grey, weathering grey; moderately resistant; sharp lower contact.
S34-1	0.4	35.4	Claystone; c-s; poor sorting; 4% dark minerals, 4% carbonaceous material; 2mm lamination; bioturbated; medium grey, weathering grey; recessive; sharp lower contact.
S35-1	0.45	35.8	Siltstone; moderate sorting; 0% dark minerals, 0% carbonaceous material; light grey, weathering grey; sharp lower contact; resistant.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S36-1	0.25	36.1	Siltstone; c-s; moderate sorting; angular clasts; 5% dark minerals, 1% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.
S37-1	0.5	36.4	Siltstone, c-s; moderate sorting; bioturbated; light grey, weathering grey; resistant; sharp lower contact.
S38-1	0.25	36.9	Sandstone; very fine (c-vf) grained; angular (va-sa) clasts; poor sorting; 3% dark minerals, 0% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.
S39-1	0.3	37.1	Sandstone, very fine (c-vf) grained; subangular (a-sa) clasts; poor sorting; 5% dark minerals, 2% carbonaceous material; medium grey, weathering grey; resistant; sharp lower contact.
S40-1	0.4	37.5	Claystone, c-s; poor sorting; mud clasts; medium grey, weathering grey; recessive; sharp lower contact.
S41-1	0.4	38.0	Sandstone, fine (s-f) grained; poor sorting; subangular (a-sr) clasts; 15% dark minerals, 0% carbonaceous material; mud clasts; occasional plant remains; medium grey, weathering grey; moderately resistant; sharp lower contact.
S42-1	1.75	39.5	Claystone; well sorted; 0% dark minerals, 0% carbonaceous material; bioturbated; light grey, weathering grey; moderately resistant; sharp lower contact.
S43-1	0.6	40.2	Siltstone, c-s; moderate sorting; light grey, weathering grey; resistant; sharp lower contact.
S44-1	0.1	40.5	Claystone; well sorted; occasional plant remains; medium grey, weathering grey; recessive; sharp lower contact.
S45-1	0.4	40.8	Sandstone, fine (s-f) grained; poor sorting; angular (a-sa) clasts; 12% dark minerals, 6% carbonaceous material; occasional plant remains; medium grey, weathering grey; resistant; sharp lower contact.
S46-1	0.2	41.1	Sandstone, medium (vf-m) grained; poor sorting; angular (va-sa) clasts; 20% dark minerals, 3% carbonaceous material; medium grey, weathering grey; resistant; gradational lower contact.
S47-1	0.7	41.5	Claystone; well sorted; 0% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.
S48-1	0.4	42.1	Siltstone, c-s; poor sorting; medium grey, weathering grey; recessive; sharp lower contact.
S49-1	0.4	42.5	Claystone; moderate sorting; occasional plant remains; medium grey, weathering grey; recessive; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S50-1	0.3	42.8	Siltstone; c-vf; poor sorting; subangular (a-sr) clasts; 0% carbonaceous material; medium grey, weathering grey; moderately resistant; sharp lower contact.
S51-1	0.33	43.2	Claystone; graphitic, sheared, fault; dark grey, weathering grey; recessive; sharp lower contact.
S52-1	0.4	43.5	Siltstone, c-s; poor sorting; angular (va-sa) clasts; bioturbated; medium grey, weathering grey; moderately resistant; sharp lower contact.
S53-1	0.15	43.3	Claystone; well sorted; abundant plant remains; dark grey, weathering grey; recessive; sharp lower contact.
S54-1	1.5	45.1	Sandstone; very fine (s-vf) grained; moderate sorting; subangular (a-sr) clasts; 15% dark minerals, 7% carbonaceous material; small cross-beds; medium grey, weathering grey; resistant; sharp lower contact.
S55-1	0.5	45.5	Siltstone; c-s; poor sorting; subangular (sa-sr) clasts; 5% dark minerals, 0% carbonaceous material; medium grey, weathering grey; moderately resistant; sharp lower contact.
S56-1	0.3	46.1	Sandstone, fine (c-f) grained; angular (a-sr) clasts; poor sorting; 5% dark minerals, 1% carbonaceous material; mud clasts; medium grey, weathering grey; resistant; erosional lower contact.
S57-1	0.5	46.5	Siltstone; well sorted; 1% dark minerals, 0% carbonaceous material, medium grey, weathering grey; moderately resistant; sharp lower contact.
S58-1	0.3	46.8	Sandstone, very fine (s-f) grained; 6% dark minerals, 2% carbonaceous material; 2mm laminations; medium grey, weathering brown; resistant; sharp lower contact.
S59-1	0.4	47.2	Same as S58-1.
S60-1	0.5	47.6	Siltstone; c-vf; moderate sorting; angular (va-sa) clasts; 5% dark minerals, 0% carbonaceous material; asymmetrical ripple; brown grey, weathering brown; resistant; sharp lower contact.
S61-1	0.25	48.0	Claystone; well sorted; occasional plant remains; dark grey, weathering grey; recessive; sharp lower contact.
S62-1	0.22	48.2	Sandstone; very fine (s-vf) grained; angular (va-sa) clasts; moderate sorting; 7% dark minerals, 3% carbonaceous material; 3mm laminations; asymmetrical ripples; medium grey, weathering grey; recessive; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S63-1	0.78	49.0	Sandstone, medium (vf-m) grained; moderate sorting; angular (va-sr) clasts; 20% dark minerals, 5% carbonaceous material; 1mm laminations; asymmetrical ripples; brown grey, weathering light grey; resistant; sharp lower contact.
S64-1	1.1	50.1	Sandstone, very fine (c-vf) grained; moderate sorting; angular (va-sa) clasts; 3% dark minerals, 0% carbonaceous material; 2mm laminations; asymmetrical ripples; light grey, weathering brown; resistant; sharp lower contact.
S65-1	1.2	51.2	Sandstone, medium (s-m) grained; poor sorting; subangular (a-sr) clasts; 5% dark minerals, 1% carbonaceous material; brown grey, weathering grey; resistant; sharp lower contact.
S66-1	2.5	53.8	Claystone, recessive.
S67-1	2.5	55.9	Sandstone, very fine; well sorted; subangular (a-r) clasts; 5% dark minerals, 1% carbonaceous material; light grey, weathering grey; moderately resistant; sharp lower contact.
S68-1	0.2	56.4	Claystone; no sample.
S69-1	2.0	58.5	Sandstone; no sample.
S70-1	1.1	59.6	Shale; no sample.
S71-1	0.85	60.1	Sandstone; fine (vf-f) grained; moderate sorting; subangular (sa-sr) clasts; 15% dark minerals, 10% carbonaceous material; large trough cross-beds; medium grey, weathering grey; resistant; sharp lower contact.
S72-1	0.2	60.6	Claystone; well sorted; 1mm laminations; dark grey, weathering grey; recessive; sharp lower contact.
S73-1	0.6	61.1	Siltstone; c-s; moderate sorting; 7% dark minerals, 2% carbonaceous material; small trough cross-beds; medium grey, weathering brown grey; resistant; sharp lower contact.
S74-1	1.7	62.5	Sandstone, medium (vf-m) grained; poor sorting; subangular (sa-sr) clasts; 10% dark minerals, 2% carbonaceous material; small trough cross-beds; light grey, weathering brown grey; resistant; sharp lower contact.
S75-1	0.3	63.1	Claystone; c-s; moderate sorting; calcareous concretions; dark grey, weathering grey; recessive; sharp lower contact.
S76-1	0.5	63.5	Siltstone; s-vf; moderate sorting; angular (a-sa) clasts; 3% dark minerals, 1% carbonaceous material; medium grey, weathering brown; resistant; sharp lower contact.

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Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S77-1	0.25	64.0	Claystone; c-s; moderate sorting; 1% dark minerals; dark grey, weathering grey; recessive; sharp lower contact.
S78-1	1.7	65.5	Siltstone; c-s; poor sorting; 1% dark minerals, 0% carbonaceous material; light grey, weathering grey; resistant; sharp lower contact.
S79-1	1.4	66.9	Sandstone; medium (f-m) grained; moderate sorting; angular (a-sr) clasts; 5% dark minerals, 1% carbonaceous material; large trough cross-beds; light grey, weathering grey; resistant; sharp lower contact.
S80-1	1.1	68.2	Siltstone; c-s; moderate sorting; 2% dark minerals, 1% carbonaceous material; light grey, weathering grey; resistant; gradational lower contact.
S81-1	0.28	68.4	Claystone; c-s; poor sorting; 1% dark minerals, 1% carbonaceous material; light grey, weathering grey; recessive; sharp lower contact.
S82-1	1.4	69.5	Same as S81-1.
S83-1	1.6	71.4	Claystone; c-s; poor sorting; dark grey, weathering grey; recessive; sharp lower contact.
S84-1	1.0	72.3	Sandstone, medium (f-m) grained; moderate sorting; angular (a-sr) clasts; 10% dark minerals, 4% carbonaceous material; medium grey, weathering grey; moderately resistant; sharp lower contact.
S85-1	2.15	74.2	Siltstone, c-vf; poor sorting; 3% dark minerals, 0% carbonaceous material; light grey, weathering grey; moderately resistant; sharp lower contact.
S86-1	0.55	74.9	Same as S85-1.
S87-1	0.6	75.5	Claystone; moderate sorting; light grey, weathering grey; recessive; sharp lower contact.
S88-1	0.4	76.1	Same as S87-1.
S89-1	0.45	76.5	Claystone, c-s; moderate sorting; rare plant remains; dark grey, weathering grey; recessive; sharp lower contact.
S90-1	0.7	77.2	Sandstone, very fine (s-vf) grained; well sorted; angular (va-sa) clasts; 12% dark minerals, 2% carbonaceous material; light grey, weathering brown grey; moderately resistant; sharp lower contact.
S91-1	1.4	78.5	Claystone; c-s; moderate sorting; 0% dark minerals, 0% carbonaceous material; light grey, weathering brown grey; recessive; gradational lower contact.
S92-1	0.8	79.4	Siltstone; well sorted; 1% dark minerals, 0% carbonaceous material; light grey, weathering grey; moderately resistant; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S93-1	2.0	81.5	Siltstone; c-s; poor sorting; light grey, weathering grey; recessive; sharp lower contact.
S94-1	0.25	81.8	Siltstone; well sorted; light grey, weathering brown; recessive; sharp lower contact.
S95-1	0.45	85.8	Same as S94-1.
S96-1	0.9	86.5	Claystone; well sorted; 1% dark minerals, 0% carbonaceous material; light grey, weathering brown; recessive; sharp lower contact.
S97-1	0.35	87.1	Claystone; c-s; poor sorting; dark grey, weathering grey; recessive; sharp lower contact.
S98-1	0.8	87.8	Sandstone; very fine (c-vf) grained; moderate sorting; subangular (a-sr) clasts; 6% dark minerals, 2% carbonaceous material; medium grey, weathering grey; moderately resistant; sharp lower contact.
	0.4	88.8	Covered.
S99-1	0.65	89.4	Siltstone; moderate sorting; subangular (a-sr) clasts; 3% dark minerals, 1% carbonaceous material; light grey, weathering grey; moderately resistant; sharp lower contact.
S100-1	0.7	90.1	Claystone; well sorted; occasional plant remains; dark grey, weathering grey; recessive; sharp lower contact.
S101-1	1.7	91.5	Siltstone; well sorted; subrounded (sa-sr) clasts; 2% dark minerals, 0% carbonaceous material; light grey, weathering grey; moderately resistant; sharp lower contact.
S102-1	2.0	93.4	Claystone; well sorted; light grey, weathering grey; recessive; sharp lower contact.
S103-1	1.8	95.4	Siltstone; c-s; poor sorting; 1% dark minerals, 0% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.
S104-1	0.2	95.8	Sandstone, very fine (c-vf) grained; poor sorting; 5% dark minerals, 2% carbonaceous material; small cross-beds; light grey, weathering grey; resistant; sharp lower contact.
S105-1	0.28	96.1	Same as S104-1.
S106-1	0.68	96.3	Siltstone; c-vf; poor sorting; 1% dark minerals, 0% carbonaceous material; 2mm laminations; bioturbated; dark grey, weathering grey; moderately resistant; sharp lower contact.
S107-1	0.9	97.6	Siltstone; well sorted; angular (va-sa) clasts; 3% dark minerals, 1% carbonaceous material; calcareous concretions; brown, weathering grey; resistant; sharp lower contact.
S108-1	0.25	97.9	Sandstone, very fine (c-vf) grained; poor sorting; angular (va-sa) clasts; 7% dark minerals, 2% carbonaceous material; light grey, weathering grey; recessive; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S109-1	0.4	98.2	Claystone; well sorted; green grey, weathering grey; recessive; gradational lower contact.
	1.4	99.8	Covered.
S110-1	0.7	100.5	Sandstone, very fine (c-vf) grained; moderate sorting; subangular (sa-sr) clasts; 3% dark minerals, 0% carbonaceous material; medium grey, weathering grey; moderately resistant; sharp lower contact.
S111-1	0.7	101.1	Siltstone, c-vf; moderate sorting; 1% dark minerals, 0% carbonaceous material; medium grey, weathering grey; moderately resistant; sharp lower contact.
S112-1	0.3	101.2	Claystone; well sorted; green grey, weathering grey; recessive; gradational lower contact.
S113-1	0.7	102.1	Claystone, c-s; well sorted; medium grey, weathering grey; recessive; gradational lower contact.
S114-1	0.4	102.4	Siltstone; c-s; well sorted; angular (va-sr) clasts; 1% dark minerals, 0% carbonaceous material; light grey, weathering grey; moderately resistant; sharp lower contact.
S115-1	1.3	103.5	Same as S114-1.
	2.0	105.8	Covered.
S116-1	1.15	106.8	Claystone; c-s; moderate sorting; green grey, weathering grey; recessive.
S117-1	0.85	107.5	Claystone; c-s; poor sorting; bioturbated; dark green grey, weathering grey; 1% dark minerals, 0% carbonaceous material; recessive; gradational lower contact.
S118-1	0.25	108.1	Same as S117-1.
S119-1	0.7	108.8	Claystone; well sorted; 0% dark minerals, 0% carbonaceous material; dark green grey, weathering grey; recessive; sharp lower contact.
S120-1	1.1	109.5	Siltstone; c-s; poor sorting; grey, weathering brown grey; recessive; sharp lower contact.
S121-1	0.3	110.1	Claystone; c-s; poor sorting; 1% dark minerals, 1% carbonaceous material; medium grey, weathering grey; recessive; gradational lower contact.
	1.0	111.2	Covered.
S122-1	0.2	111.3	Siltstone; c-vf; poor sorting; angular (va-sa) clasts; 2% dark minerals, 1% carbonaceous material; green grey, weathering grey; recessive.
	1.0	112.4	Covered.
S123-1	0.2	112.6	Siltstone; c-s; poor sorting; 3% dark minerals, 1% carbonaceous material; brown grey, weathering grey; recessive.
	1.25	113.8	Covered.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S124-1	0.6	114.3	Sandstone, very fine (c-vf) grained; poor sorting; subrounded (sa-sr) clasts; 1% dark minerals, 0% carbonaceous material; medium grey, weathering grey; resistant.
	3.1	117.5	Covered.
S125-1	0.8	118.2	Claystone; c-s; well sorted; 1% dark minerals, 0% carbonaceous material; calcareous concretions; medium grey, weathering grey; resistant.
S126-1	0.8	119.1	Sandstone, fine (vf-f) grained; moderate sorting; subangular (a-sr) clasts; 10% dark minerals, 3% carbonaceous material; medium grey, weathering brown grey; resistant; sharp lower contact.
S127-1	0.15	119.2	Claystone; dark grey; recessive; sharp lower contact.
S128-1	0.15	119.4	Sandstone, medium (vf-m) grained; moderate sorting; subangular (a-sr) clasts; 12% dark minerals, 5% carbonaceous material; medium grey, weathering brown grey; moderately resistant; sharp lower contact.
S129-1	0.45	119.9	Claystone; well sorted; 0% carbonaceous material; dark grey, weathering grey; recessive; sharp lower contact.
S130-1	0.35	120.1	Claystone; c-s; moderate sorting; 1% dark minerals, 0% carbonaceous material; medium grey, weathering grey; moderately resistant; sharp lower contact.
S131-1	0.55	120.5	Claystone; well sorted; 0% dark minerals, 0% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.
S132-1	0.45	121.1	Siltstone; c-s; poor sorting; 5% dark minerals, 0% carbonaceous material; medium grey, weathering brown grey; moderately resistant; sharp lower contact.
S133-1	0.35	121.5	Claystone; c-s; poor sorting; dark green grey, weathering brown grey; recessive; gradational lower contact.
	1.4	122.9	Covered.
S134-1	0.2	123.1	Sandstone, fine (s-f) grained; poor sorting; subangular (a-sr) clasts; 15% dark minerals, 5% carbonaceous material; medium grey, weathering grey; moderately resistant; sharp lower contact.
S135-1	1.4	123.5	Claystone; c-s; poor sorting; dark green grey, weathering grey; recessive; sharp lower contact.
S136-1	1.0	125.3	Sandstone, very fine (c-vf) grained; poor sorting; subangular (a-sr) clasts; 8% dark minerals, 3% carbonaceous material; medium grey, weathering brown grey; resistant; sharp lower contact.
	4.45	129.7	Covered.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S137-1	0.6	130.8	Siltstone; c-s; moderate sorting; 3% dark minerals, 2% carbonaceous material; medium grey, weathering brown grey; moderately resistant; sharp lower contact.
S138-1	0.3	130.0	Claystone; c-s; well sorted; dark green grey, weathering grey; recessive; sharp lower contact.
S139-1	0.4	131.2	Sandstone, very fine (c-vf) grained; poor sorting; subangular (a-sr) clasts; 5% dark minerals, 2% carbonaceous material; medium grey, weathering grey; resistant; sharp lower contact.
	0.4	131.6	Covered.
S140-1	0.35	132.1	Siltstone; c-s; moderate sorting; 4% dark minerals, 2% carbonaceous material; green grey, weathering brown grey; moderately resistant.
	1.25	133.3	Covered.
S141-1	0.3	133.5	Siltstone; c-vf; poor sorting; subangular (a-sr) clasts; 3% dark minerals, 1% carbonaceous material; green grey, weathering brown grey; resistant; sharp lower contact.
	0.6	134.1	Covered.
S142-1	0.4	134.5	Siltstone; c-f; poor sorting; angular (va-sa) clasts; 3% dark minerals, 1% carbonaceous material; green grey, weathering grey; moderately resistant; sharp lower contact.
	0.7	135.2	Covered.
S143-1	1.6	135.6	Sandstone, very fine (c-vf) grained; poor sorting; 5% dark minerals, 2% carbonaceous material; light grey, weathering light grey; resistant; sharp lower contact.
			Base of Calcareous Member
S144-1	0.7	136.3	Sandstone, very fine grained; calcareous; occasional plant remains.
S145-1	0.75	137.05	Limestone, very fine grained; grey, weathering light grey; sharp lower contact.
S146-1	0.9	137.9	Claystone; black; sheared; faulted?; sharp lower contact.
S147-1	1.65	139.6	Limestone, very fine grained; ripple marks; abundant mollusc fossils; resistant; sharp lower contact.
S148-1	1.1	140.7	Claystone; black; recessive; sharp lower contact.
S149-1	0.8	141.5	Limestone, very fine grained; rare mollusc fossils; resistant; sharp lower contact.
S150-1	3.5	145.0	Claystone, black; recessive; sharp lower contact.
S151-1	1.1	146.1	Limestone, very fine grained; grey; moderately resistant; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S152-1	1.5	147.6	Limestone, fine grained; symmetrical ripple marks; resistant; sharp lower contact; abundant mollusc fossils.
S153-1	2.5	150.1	Claystone, black; resistant; sharp lower contact.
S154-1	1.6	151.7	Limestone; very fine laminations; tool marks; occasional plant remains; resistant; gradational lower contact.
S155-1	3.0	154.7	Claystone, black; calcareous; moderately resistant; gradational lower contact.
S156-1	1.7	156.4	Limestone, very fine grained; finely laminated; resistant; gradational lower contact.
	2.0	158.4	Covered, may be fault zone.
S157-1	1.1	159.9	Sandstone, fine grained; grey; resistant; sharp lower contact.
S158-1	0.8	160.3	Claystone; grey; moderately resistant; sharp lower contact.
S159-1	2.5	162.8	Limestone, very fine grained; finely laminated; moderately resistant; sharp lower contact.
S160-1	1.5	164.3	Limestone, fine grained; grey; resistant; gradational lower contact.
S161-1	2.5	166.8	Claystone; dark grey; calcareous concretions; moderately resistant; gradational lower contact; some minor faulting.
S162-1	0.3	167.1	Claystone, black; recessive; sharp lower contact.
			Top of Gladstone Formation
			Total thickness is 167 metres
			Beaver Mines Formation
S163-1	1.4	170.5	Sandstone, fine (vf-f) grained; poor sorting; angular (va-sr) clasts; 15 dark minerals, 0% carbonaceous material; tool marks at base; dark green grey, weathering brown grey; resistant; sharp lower contact.
S164-1	0.55	171.4	Claystone; well sorted; 0% carbonaceous material; dark green grey, weathering grey; recessive; sharp lower contact.
S165-1	0.25	171.5	Sandstone, medium (s-m) grained; poor sorting; angular (va-sa) clasts; 10% dark minerals, 3% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
S166-1	0.8	172.4	Claystone; well sorted; 0% carbonaceous material; olive black, weathering grey; recessive; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S167-1	1.7	173.9	Sandstone, medium (f-m) grained; moderate sorting; angular (va-sa) clasts; 20% dark minerals, 5% carbonaceous material; large trough cross-beds; mud clasts; dark green grey, weathering grey; resistant; sharp lower contact.
S168-1	0.3	174.4	Claystone, silty; moderate sorting; 0% carbonaceous material; dark green grey, weathering grey; recessive; gradational lower contact.
S169-1	0.8	175.2	Sandstone, very fine (c-vf) grained; poor sorting; very angular (va-sa) clasts; 25% dark minerals, 8% carbonaceous material; dark green grey, weathering grey; resistant; gradational lower contact.
	2.0	177.2	Covered.
S170-1	2.0	177.3	Siltstone, c-s; poor sorting; angular (va-sa) clasts; 10% dark minerals, 3% carbonaceous material; 8mm laminations; small cross-beds; dark green grey, weathering grey; resistant.
S170-2	0.3	179.3	Claystone, silty; poor sorting; 15% dark minerals, 0% carbonaceous material; dark green grey, weathering grey; resistant.
S171-1	0.25	179.9	Claystone; well sorted; 0% carbonaceous material; dark grey, weathering grey; recessive; sharp lower contact.
S172-1	0.6	180.4	Siltstone; c-vf; poor sorting; angular (va-sa) clasts; 25% dark minerals, 10% carbonaceous material; small cross-beds; dark green grey, weathering grey; resistant; sharp lower contact.
S173-1	0.25	180.6	Claystone; well sorted; 5% carbonaceous material; occasional plant fossils; dark grey, weathering grey; recessive; gradational lower contact.
S174-1	0.33	181.1	Siltstone, c-vf; poor sorting; very angular (va-a) clasts; 30% dark minerals, 15% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
S175-1	0.3	181.3	Same as S174-1.
S176-1	0.25	181.5	Sandstone, very fine (s-f) grained; poor sorting; angular (va-sa) clasts; 30% dark minerals, 15% carbonaceous material; dark green grey, weathering brown grey; moderately resistant; sharp lower contact.
S177-1	0.35	181.9	Sandstone, medium (f-m) grained; moderate sorting; subangular (a-sr) clasts; 20% dark minerals, 2% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
S178-1	0.85	182.7	Sandstone, fine (vf-m) grained; moderate sorting; subangular (a-sr) clasts; 10% dark minerals, 0% carbonaceous material; olive grey, weathering brown grey; resistant; gradational lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S179-1	2.0	184.5	Sandstone, fine (vf-f) grained; poor sorting; subangular (sa-sr) clasts; 15% dark minerals, 5% carbonaceous material; dark green grey, weathering brown grey; resistant; gradational lower contact.
S180-1	2.0	186.5	Claystone, silty; poor sorting; 3% carbonaceous material; bioturbated; dark green grey, weathering grey; recessive; sharp lower contact.
S181-1	2.0	186.9	Sandstone, fine (f-m) grained; poor sorting; subangular (a-sr) clasts; 15% dark minerals, 5% carbonaceous material; olive grey, weathering grey; resistant; sharp lower contact.
S181-2	2.0	188.9	Sandstone, medium (f-m) grained; moderate sorting; angular (va-sa) clasts; 25% dark minerals, 5% carbonaceous material; dark green grey, weathering grey; resistant; gradational lower contact. Laterally continuous 5cm bed of claystone at top.
S181-3	2.0	190.9	Sandstone, fine (vf-f) grained; poor sorting; angular (a-sa) clasts; 20% dark minerals, 8% carbonaceous material; dark green grey, weathering grey; resistant; gradational lower contact.
S181-4	2.0	192.9	Same as S181-3.
S181-5	2.0	194.9	Sandstone, very fine (vf-f) grained; angular (a-sa) clasts; poor sorting; 20% dark minerals, 5% carbonaceous material; 3mm laminations; dark green grey, weathering grey; resistant; gradational lower contact.
S181-6	2.0	196.9	Sandstone, medium (vf-m) grained; poor sorting; subangular (a-sa) clasts; 25% dark minerals, 8% carbonaceous material; dark green grey, weathering grey; resistant; gradational lower contact.
S181-7	1.6	198.9	Sandstone, medium (f-m) grained; moderate sorting; angular (va-sa) clasts; 15% dark minerals, 1% carbonaceous material; olive grey, weathering grey; resistant; gradational lower contact.
S182-1	0.45	200.8	Siltstone, c-s; poor sorting; 5% carbonaceous material; 1mm laminations; dark green grey, weathering grey; resistant; gradational lower contact.
S183-1	0.38	201.2	Claystone, silty; poor sorting; 1mm laminations; bioturbated; dark green grey, weathering grey; moderately resistant; gradational lower contact.
S184-1	0.4	201.5	Sandstone, very fine (s-vf) grained; moderate sorting; subangular (sa-sr) clasts; mud clasts; dark green grey, weathering grey; 25% dark minerals, 5% carbonaceous material; resistant; sharp lower contact.
S185-1	0.5	202.5	Claystone, silty; poor sorting; dark green grey, weathering grey; resistant; gradational lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S186-1	0.8	202.7	Siltstone; c-s; poor sorting; subangular (a-sa) clasts; 30% dark minerals, 10% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
S187-1	0.3	203.1	Claystone; well sorted; 0% carbonaceous material; rare plant fossils; bioturbated; green black, weathering black; recessive; sharp lower contact.
S188-1	1.1	203.9	Claystone, silty; poor sorting; 8% carbonaceous material; occasional plant remains; dark green grey, weathering grey; resistant; sharp lower contact.
S189-1	1.6	205.1	Sandstone, very fine (s-f) grained; poor sorting; subangular (sa-sr) clasts; 10% dark minerals, 5% carbonaceous material; 3mm laminations; mud clasts; dark green grey, weathering grey; recessive; sharp lower contact.
S190-1	1.3	207.1	Claystone; well sorted; 0% carbonaceous material; 1cm laminations; rare plant remains; olive black, weathering grey; moderately resistant; sharp lower contact.
S191-1	0.3	207.5	Combined with S190-1.
S192-1	0.35	207.8	Sandstone, very fine (s-vf) grained; poor sorting; subangular (a-sr) clasts; 20% dark minerals, 10% carbonaceous material; occasional plant remains; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S193-1	0.31	208.1	Siltstone; c-vf; poor sorting; angular (a-sa) clasts; 10% carbonaceous material; occasional plant remains; dark green grey, weathering grey; moderately resistant; gradational lower contact.
S194-1	0.75	208.9	Claystone, silty; moderate sorting; 10% carbonaceous material; 1mm laminations; rare plant remains; green black, weathering grey; moderately resistant; gradational lower contact.
S195-1	1.4	210.3	Sandstone, fine (vf-f) grained; poor sorting; angular (va-sa) clasts; 20% dark minerals, 5% carbonaceous material; dark green grey, weathering green grey; resistant; sharp lower contact.
	0.95	211.2	Covered.
S196-1	1.6	212.5	Claystone; well sorted; bioturbated; dark green grey, weathering green grey; recessive.
S197-1	2.0	213.1	Sandstone, fine (vf-m) grained; moderate sorting; subangular (sa-sr) clasts; 15% dark minerals, 2% carbonaceous material; dark green grey, weathering green grey; resistant; sharp lower contact.
S197-2	2.0	214.95	Sandstone, fine (vf-f) grained; poor sorting; angular (a-sa) clasts; 30% dark minerals, 15% carbonaceous material; dark green grey, weathering green grey; resistant; gradational lower contact.

Sample Number	Thickness (metres)	Position (metres from base)	Description
S197-3	2.0	216.95	Sandstone, fine (vf-f) grained; poor sorting; angular (a-sa) clasts; 15% dark minerals, 5% carbonaceous material; dark green grey, weathering green grey; resistant; gradational lower contact.
S198-1	0.95	221.3	Siltstone; c-vf; poor sorting; angular (va-a) clasts; 25% dark minerals, 12% carbonaceous material; 2mm laminations; green black, weathering green grey; resistant; sharp lower contact.
S199-1	0.3	221.6	Claystone, silty; poor sorting; 10% carbonaceous material; rare plant remains; bioturbated; black, weathering grey; recessive; sharp lower contact.
S200-1	0.4	222.1	Same as S199-1.
S201-1	0.9	222.9	Siltstone; c-vf; poor sorting; angular (a-sa) clasts; 7% dark minerals, 3% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
S202-1	0.3	223.2	Siltstone; c-s; poor sorting; angular (a-sa) clasts; 7% dark minerals, 3% carbonaceous material; dark green grey, weathering grey; recessive; gradational lower contact.
S203-1	0.6	223.8	Siltstone; c-vf; poor sorting; subangular (a-sa) clasts; 7% dark minerals, 2% carbonaceous material; dark green grey, weathering green grey; recessive; gradational lower contact.
S204-1	1.85	225.2	Claystone; well sorted; 0% carbonaceous material; bioturbated; green black, weathering green; recessive; sharp lower contact.
S205-1	0.6	226.1	Siltstone; c-s; poor sorting; angular (va-sa) clasts; 10% dark minerals, 7% carbonaceous material; dark green grey, weathering green grey; moderately resistant; sharp lower contact.
S206-1	2.4	228.1	Claystone; c-s; poor sorting; 15% dark minerals, 8% carbonaceous material; bioturbated; dark green grey, weathering green grey; recessive.
S207-1	0.55	229.1	Siltstone; c-s; poor sorting; angular (va-sa) clasts; 10% dark minerals, 3% carbonaceous material; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S208-1	0.3	229.5	Claystone; moderate sorting; occasional plant remains; bioturbated; green black, weathering grey.
S209-1	0.53	230.1	Sandstone; very fine (s-vf) grained; poor sorting; angular (va-sa) clasts; 20% dark minerals, 8% carbonaceous material; mud clasts; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S210-1	0.3	230.3	Claystone;c-s; moderate sorting; 0% carbonaceous material; green black, weathering grey; recessive; gradational lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S211-1	0.2	230.5	Sandstone; very fine (s-f) grained; poor sorting; subangular (a-sa) clasts; 20% dark minerals, 5% carbonaceous material; 2cm laminations; small trough cross-beds; dark green grey; moderately resistant; sharp lower contact.
S212-1	0.6	231.2	Sandstone; very fine (s-vf) grained; poor sorting; angular (va-sa) clasts; 25% dark minerals, 12% carbonaceous material; bioturbated; dark green grey, weathering green grey; moderately resistant; gradational lower contact.
S213-1	0.53	231.5	Siltstone; c-s; poor sorting; angular (va-a) clasts; 25% dark minerals, 12% carbonaceous material; occasional plant remains; dark green grey, weathering green grey; recessive; gradational lower contact.
S214-1	0.65	232.2	Sandstone; very fine (c-vf) grained; poor sorting; angular (a-sa) clasts; 15% dark minerals, 5% carbonaceous material; dark green grey, weathering green grey; recessive; sharp lower contact.
S215-1	3.9	234.5	Siltstone; c-s; well sorted; 5% dark minerals, 5% carbonaceous material; dark green grey, weathering green grey; recessive; sharp lower contact.
S216-1	2.4	236.9	Sandstone, very fine (s-vf) grained; moderate sorting; very angular (va-a) clasts; 15% dark minerals, 10% carbonaceous material; mud clasts; occasional plant remains; dark green grey, weathering grey; resistant; sharp lower contact.
S217-1	0.9	238.5	Sandstone, fine (vf-m) grained; poor sorting; subangular (a-sa) clasts; 8% dark minerals, 3% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
S218-1	0.9	239.5	Claystone; c-s; moderate sorting; 30% dark minerals, 20% carbonaceous material; bioturbated; dark grey, weathering grey; recessive; sharp lower contact.
S219-1	0.4	240.1	Siltstone; c-s; poor sorting; 25% dark minerals, 15% carbonaceous material; 0.5 cm laminations; small tangential cross-beds; dark green grey, weathering brown grey; recessive; sharp lower contact.
S220-1	1.4	241.2	Claystone; well sorted; 1mm laminations; green black, weathering grey; recessive; sharp lower contact.
S221-1	0.5	24.9	Siltstone; well sorted; very angular (va-a) clasts; 20% dark minerals, 10% carbonaceous material; 0.3cm laminations; small trough cross-beds; olive grey, weathering brown grey; moderately resistant; gradational lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S222-1	1.5	242.9	Claystone; c-s; poor sorting; 30% dark minerals, 15% carbonaceous material; 2mm laminations; symmetrical ripple marks; green black, weathering grey; moderately resistant; sharp lower contact.
S223-1	0.5	243.9	Siltstone; c-s; poor sorting; 8% dark minerals, 3% carbonaceous material; dark green grey, weathering grey; recessive; sharp lower contact.
S224-1	0.5	244.1	Sandstone; fine (s-f) grained; poor sorting; subangular (a-sa) clasts; 5% dark minerals, 0% carbonaceous material; mud clasts; dark green grey, weathering green grey; moderately resistant; sharp lower contact.
S225-1	0.75	245.1	Claystone; c-s; poor sorting; 6% dark minerals, 2% carbonaceous material; 0.4cm laminations; dark green grey, weathering grey; moderately resistant; gradational lower contact.
S226-1	1.05	246.2	Same as S225-1.
S227-1	1.20	246.9	Sandstone; very fine (s-vf) grained; poor sorting; 10% dark minerals, 6% carbonaceous material; 0.2cm laminations; mud clasts; dark green grey, weathering grey; resistant; gradational lower contact.
S228-1	0.4	247.8	Claystone; c-s; moderate sorting; 4mm laminations; summetrical ripple marks; dark green grey, weathering brown grey; recessive; gradational lower contact.
S229-1	1.65	249.1	Siltstone; c-s; poor sorting; 10% dark minerals, 5% carbonaceous material; 2mm laminations; dark green grey, weathering brown grey; moderately resistant; sharp lower contact.
S230-1	2.55	251.8	Claystone; c-s; poor sorting; 5% dark minerals, 1% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
S231-1	1.3	253.2	Same as S230-1.
S232-1	0.45	253.7	Siltstone; c-s; moderate sorting; angular (a-sa) clasts; 10% dark minerals, 3% carbonaceous material; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S233-1	0.5	254.1	Claystone; c-s; poor sorting; dark green grey, weathering grey; recessive; sharp lower contact.
S234-1	2.0	254.3	Sandstone; fine (vf-f) grained; moderate sorting; angular (a-sa) clasts; 15% dark minerals, 5% carbonaceous material; mud clasts; dark green grey, weathering grey; resistant; sharp lower contact.
S234-2	1.4	256.3	Sandstone; very fine (s-vf) grained; moderate sorting; angular (va-a) clasts; 12% dark minerals, 3% carbonaceous material; calcareous concretions; dark green grey, weathering grey; resistant; gradational lower contact.

Sample Number	Thickness (metres)	Position (metres from base)	Description
S235-1	1.3	258.7	Claystone; well sorted; calcareous concretions; dark green grey, weathering grey; recessive; gradational lower contact.
S236-1	0.3	259.2	Sandstone; fine (vf-m) moderate sorting; angular (a-sa) clasts; 10% dark minerals, 4% carbonaceous material; mud clasts; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S237-1	2.3	260.5	Claystone; c-s; moderate sorting; bioturbated; dark green grey, weathering green; recessive; gradational lower contact.
S238-1	2.0	263.1	Same as S237-1.
S239-1	0.45	264.1	Siltstone; c-s; poor sorting; 15% dark minerals, 8% carbonaceous material; dark green grey, weathering green grey; moderately resistant; sharp lower contact.
S240-1	0.25	264.3	Sandstone, fine (s-f) grained; poor sorting; angular (a-sa) clasts; 8% dark minerals, 3% carbonaceous material; dark green grey, weathering green grey; moderately resistant; gradational lower contact.
S241-1	2.0	264.5	Siltstone; c-s; poor sorting; angular (a-sa) clasts; 5% dark minerals, 3% carbonaceous material; 1cm laminations; mud clasts; dark green grey, weathering grey; recessive; gradational lower contact.
S241-2	2.0	266.3	Claystone; well sorted; occasional plant remains; dark green grey, weathering grey; recessive; gradational lower contact.
S241-3		268.3	Same as S241-2.
S242-1		269.5	Same as S241-2.
S243-1	1.6	270.9	Siltstone; c-s; poor sorting; angular (va-sa) clasts; 15% dark minerals, 10% carbonaceous material; small scale tangential cross-beds; occasional plant remains; dark green grey, weathering grey; recessive; sharp lower contact.
S244-1	1.85	272.6	Sandstone, very fine (vf-f) grained; poor sorting; angular (a-sa) clasts; 15% dark minerals, 5% carbonaceous material; dark green grey, weathering green grey; moderately resistant; sharp lower contact.
S245-1	2.1	273.05	Claystone; c-s; moderate sorting; 2mm laminations; small tangential cross-beds; dark green grey, weathering grey; recessive; sharp lower contact.
S245-2	1.5	275.1	Claystone; c-s; poor sorting; dark green grey, weathering grey; recessive; gradational lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S246-1	0.2	276.7	Claystone; c-s; poor sorting; 8% carbonaceous material; symmetrical ripples; bioturbated; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S247-1		277.3	Same as S246-1.
S248-1	2.1	278.9	Claystone; moderate sorting; 1% carbonaceous material; dark green grey, weathering grey; recessive; gradational lower contact.
S249-1	0.4	279.3	Siltstone; no sample.
S250-1	0.25	280.1	Siltstone; c-s; poor sorting; dark green grey, weathering grey; moderately resistant; gradational lower contact.
S251-1	0.6	280.7	Claystone; c-s; moderate sorting; dark green grey, weathering grey; moderately resistant; gradational lower contact.
S252-1	0.22	281.0	Siltstone; c-s; poor sorting; 3% dark minerals, 1% carbonaceous material; mud clasts; dark green grey, weathering grey; moderate resistance; gradational lower contact.
S253-1	0.28	281.3	Siltstone; c-s; poor sorting; angular (a-sa) clasts; 3% dark minerals, 1% carbonaceous material; dark green grey, weathering grey; moderately resistant; gradational lower contact.
S254-1	1.12	282.1	Siltstone; c-s; poor sorting; angular (a-sa) clasts; 3% dark minerals, 1% carbonaceous material; 1mm laminations; dark green grey, weathering grey; recessive; sharp lower contact.
S255-1	1.35	283.1	Sandstone, very fine (s-vf) grained; poor sorting; angular (a-sa) clasts; 5% dark minerals, 2% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
S256-1	1.05	284.1	Siltstone; c-s; poor sorting; 5% dark minerals, 3% carbonaceous material; dark green grey, weathering grey; moderatly resistant; gradational lower contact.
S257-1	0.45	285.1	Claystone;c-s; moderate sorting; 1mm laminations; asymmetrical ripple marks; dark green grey, weathering grey; moderately resistant.
S258-1	0.85	286.1	Siltstone; moderate sorting; angular clasts; 2% dark minerals, 1% carbonaceous material; dark green grey, weathering grey; moderately resistant; gradational lower contact.
S259-1	0.7	286.6	Claystone; c-s; moderate sorting; 3% carbonaceous material, occasional plant remains; olive grey, weathering green grey; recessive; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S260-1	0.2	286.8	Sandstone; coarse (m-crs) grained; poorly sorted; subangular (a-sr) clasts; 7% dark minerals, 1% carbonaceous material; dark green grey, weathering grey; pebbles at base; resistant; sharp lower contact.
S620-2	0.8	287.1	Same as S260-1.
S260-3	2.0	[illegible]8.8	Sandstone, medium (f-m) grained; poor sorting; subangular (a-sa) clasts; 15% dark minerals, 7% carbonaceous material; dark green grey, weathering grey; resistant; gradational lower contact.
S260-4	2.0	290.8	Same as S260-3.
S260-5	2.0	292.8	Sandstone, fine (f-m) grained; poor sorting; subangular (a-sr) clasts; 10% dark minerals, 4% carbonaceous material; dark green grey; weathering grey; resistant; gradational lower contact.
S260-6	2.0	294.8	Sandstone, medium (f-m) grained; poor sorting; angular (a-sa) clasts; 5% dark minerals, 1% carbonaceous material; dark green grey, weathering grey; resistant; gradational lower contact.
S260-7	2.0	296.8	Same as S260-6.
S260-8	1.0	297.8	Sa[illegible]s S260-6.
S260-9	1.0	298.8	Same as S260-6.
S260-10	0.5	300.5	Same as S260-6.
S261-1	0.5	301.5	Siltstone; c-s; poor sorting; very angular (va-a) clasts; 15% dark minerals, 8% carbonaceous material; green black, weathering grey; moderately resistant; sharp lower contact.
S262-1	0.15	302.1	Claystone; c-s; moderate sorting; 0% carbonaceous material; green black, weathering grey; recessive; gradational lower contact.
S263-1	0.15	302.2	Same as S262-1.
S264-1	2.0	302.4	Sandstone, very fine (s-vf) grained; poor sorting; angular (va-a) clasts; 15% dark minerals, 8% carbonaceous material; dark green grey, weathering green grey; moderately resistant; sharp lower contact.
S264-2	1.1	304.2	Siltstone; c-s; poor sorting; angular (va-a) clasts; 15% dark minerals, 10% carbonaceous material; moderately resistant; dark green grey, weathering grey; gradational lower contact.
S265-1	0.3	305.6	Siltstone; c-s; poor sorting; 5% dark minerals, 3% carbonaceous material; green black, weathering grey; recessive; gradational lower contact.
S266-1	0.35	306.0	Claystone; c-s; poor sorting; dark green grey, weathering grey; resistant; sharp lower contact.

Sample Number	Thick- ness (metres)	Position (metres from base)	Description
S267-1	1.9	307.1	Claystone; moderate sorting; asymmetrical ripple marks; occasional plant remains; green black, weathering grey; moderately resistant; gradational lower contact.
268-1	0.8	308.5	Claystone; well sorted; dark green grey, weathering grey; moderately resistant; gradational lower contact.
S269-1	2.25	310.5	Siltstone; c-vf; moderate sorting; angular (va-sa) clasts; 5% dark minerals, 1% carbonaceous material; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S270-1	0.8	311.4	Claystone; moderate sorting; 2% dark minerals, 1% carbonaceous material; dark green grey, weathering grey; recessive; sharp lower contact.
	1.8	313.2	Covered.
S271-1	2.2	314.8	Siltstone; c-s; poor sorting; angular (va-sa) clasts; 2% dark minerals, 1% carbonaceous material; dark green grey, weathering grey; moderately resistant.
S272-1	0.4	316.1	Claystone; c-s; poor sorting; 3% dark minerals, 1% carbonaceous material; 2mm laminations; dark green grey, weathering grey; recessive; gradational lower contact.
S273-1	0.65	316.5	Siltstone; c-s; poor sorting; 4% dark minerals, 1% carbonaceous material; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S274-1	1.8	318.1	Claystone; moderate sorting; 3% dark minerals, 1% carbonaceous material; bioturbated; dark green grey, weathering grey; recessive; sharp lower contact.
	2.0	320.1	Covered.
S275-1	6.2	324.8	Claystone; well sorted; 1mm laminations; occasional plant remains; green black, weathering grey; recessive.
S276-1	0.55	327.1	Sandstone, very fine (s-vf) grained; poor soring; angular (va-sa) clasts; 5% dark minerals, 3% carbonaceous material; dark green grey, weathering brown grey; moderately resistant; sharp lower contact.
S277-1	0.33	327.6	Claystone; well sorted; dark green grey, weathering grey; recessive; gradational lower contact.
S278-1	0.18	327.8	Claystone; c-s; moderate sorting; dark green grey, weathering grey; recessive; sharp lower contact.
S279-1	0.85	328.6	Sandstone, fine (vf-f) grained; poor sorting; angular (a-sa) clasts; 10% dark minerals, 0% carbonaceous material; dark green grey, weathering brown grey; resistant; sharp lower contact.
	2.0	330.6	Covered.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S280-1	0.37	331.1	Claystone; well sorted; 5% carbonaceous material; occasional plant remains; ripple marks; green black, weathering grey; recessive; sharp lower contact.
S281-1	4.0	333.1	Same as S280-1.
S282-1	2.0	336.1	Siltstone; c-s; moderate sorting; 7% dark minerals, 3% carbonaceous material; dark green grey, weathering grey; recessive; sharp lower contact.
S283-1	0.5	336.6	Claystone; no sample; recessive; sharp lower contact.
S284-1	2.0	338.6	Siltstone; c-vf; poor sorting; angular (a-sa) clasts; 2% dark minerals, 0% carbonaceous materal; dark green grey, weathering grey; resistant; sharp lower contact.
S285-1	2.0	339.6	Sandstone, very fine (s-vf) grained; moderate sorting; angular (va-sa) clasts; 7% dark minerals, 0% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
S285-2	1.6	341.6	Sandstone, very fine (s-vf) grained; poor sorting; 6% dark minerals, 2% carbonaceous material; dark green grey, weathering grey; resistant; gradational lower contact.
S286-1	2.0	343.2	Siltstone; c-s; poor sorting; 3% dark minerals, 1% carbonaceous material; dark green grey, weathering green grey; moderately resistant; gradational lower contact.
S286-2	1.3	345.2	Siltstone; c-vf; poor sorting; 3% dark minerals, 1% carbonaceous material; bioturbated; dark green grey, weathering green grey; moderately resistant; gradational lower contact.
S287-1	2.0	346.5	Sandstone, medium (f-crs) grained; poor sorting; angular (a-sa) clasts; 10% dark minerals, 4% carbonaceous material; occasional plant remains; mud clasts; dark green grey, weathering grey; resistant; sharp lower contact.
S287-2	1.45	348.5	Same as S287-1.
S288-1	1.75	351.7	Claystone; no sample; grey; recessive; sharp lower contact.
S289-1	3.0	353.7	Claystone; moderate sorting; 0% carbonaceous material; asymmetrical ripples; green black, weathering grey; splintery; recessive; gradational lower contact.
S290-1	2.0	354.7	Siltstone; c-s; poor sorting; subangular (a-sa) clasts; 10% dark minerals, 5% carbonaceous material; asymmetrical ripples; dark green grey, weathering green grey; resistant; sharp lower contact.

Sample Number	Thick- ness (metres)	Position (metres from base)	Description
S290-2	2.0	356.7	Sandstone, very fine (s-vf) grained; poor sorting; subangular (a-sa) clasts; 10% dark minerals, 3% carbonaceous material; dark green grey, weathering green grey; resistant; gradational lower contact.
S290-3	0.7	358.7	Same as S290-2.
S291-1	3.55	361.8	Claystone; well sorted; bioturbated; dark green grey, weathering grey; recessive; sharp lower contact.
S292-1	0.65	363.5	Same as S291-1.
S293-1	0.45	363.9	Siltstone; c-s; poor sorting; 15% dark minerals, 5% carbonaceous material; 2mm laminations; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S294-1	0.45	363.4	Same as S293-1.
S295-1	0.8	365.2	Siltstone; c-s; moderate sorting; angular (a-sa) clasts; 8% dark minerals, 3% carbonaceous material; bioturbated; dark green grey, weathering grey; moderately resistant; gradational lower contact.
S296-1	1.0	365.9	Claystone; well sorted; bioturbated; dark green grey, weathering green grey; moderately resistant; sharp lower contact.
S297-1	1.1	366.9	Sandstone, very fine (c-vf) grained; poor sorting; subrounded (sa-sr) clasts; 2% dark minerals, 0% carbonaceous material; bioturbated; green grey, weathering green grey; recessive; sharp lower contact.
S298-1	0.12	367.5	Claystone; moderate sorting; bioturbated; dark green grey, weathering grey; recessive; sharp lower contact.
S299-1	2.55	369.5	Same as S298-1; very splintered.
S300-1	1.7	370.8	Sandstone, very fine (s-vf) grained; poor sorting; angular (va-sa) clasts; 10% dark minerals, 5% carbonaceous material; dark green grey, weathering green grey; resistant; sharp lower contact.
	0.3	371.1	Covered.
S301-1	0.9	372.9	Siltstone; c-vf; poor sorting; angular (va-sa) clasts; 15% dark minerals, 5% carbonaceous material; mud clasts; bioturbated; dark green grey, weathering green grey; recessive.
S302-1	2.9	374.5	Claystone; c-s; moderate sorting; 0% carbonaceous material; calcareous concretions; dark green grey, weathering green grey; recessive; sharp lower contact.
S303-1	0.65	376.4	Claystone; c-s; poor sorting; 0% carbonaceous material; mud clasts; olive grey, weathering grey; recessive; sharp lower contact.

Sample Number	Thickness (metres)	Position (metres from base)	Description
S304-1	1.8	377.9	Claystone; well sorted; dark green grey, weathering grey; splintered; moderately resistant; sharp lower contact.
S305-1	2.0	379.5	Sandstone, very fine (s-vf) grained; poor sorting; angular (va-sa) clasts; 5% dark minerals, 2% carbonaceous material; dark green grey, weathering green grey; resistant; sharp lower contact.
S306-1	0.53	380.7	Same as S305-1.
S307-1	0.88	381.5	Claystone; well sorted; dark green grey, weathering grey; recessive; gradational lower contact.
S308-1	1.4	382.9	Siltstone; c-s; poor sorting; angular (va-sa) clasts; 10% dark minerals, 4% carbonaceous material; 1mm laminations; dark green grey, weathering green grey; moderately resistant; sharp lower contact.
S309-1	0.8	383.6	Claystone; c-s; moderate sorting; bioturbated; dark green grey, weathering green grey; recessive; sharp lower contact.
	4.5	387.1	Covered.
S310-1	0.6	388.9	Siltstone; c-s; poor sorting; angular (va-sa) clasts; 6% dark minerals, 2% carbonaceous material; dark green grey, weathering grey; moderately resistant.
S311-1	1.25	389.9	Claystone; well sorted; rare plant remains; bioturbated; dark green grey, weathering green grey; recessive; sharp lower contact.
S312-1	0.45	390.4	Sandstone, very fine (s-vf) grained; poor sorting; angular (a-sa) clasts; 10% dark minerals, 4% carbonaceous material; small trough cross-beds; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S313-1	0.25	390.9	Siltstone; c-s; poor sorting; 5% dark minerals, 3% carbonaceous material; dark green grey, weathering green grey; moderately resistant; sharp lower contact.
S314-1	3.7	392.7	Claystone; c-s; moderate sorting; 10% dark minerals; bioturbated; dark green grey, weathering green; recessive; sharp lower contact.
S315-1	0.35	394.9	Siltstone; c-vf; poor sorting; angular (va-sa) clasts; 3% dark minerals, 1% carbonaceous material; dark green grey, weathering green grey; moderately resistant; sharp lower contact.
S316-1	12.5	405.4	Alternating siltstone and claystone; mottled red and green; interpreted as containing a fault thrusting the Beaver Mines over the Mill Creek.

Top of Beaver Mines Formation

Total thickness is 240 metres

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
			Mill Creek Formation
S317-1	0.8	408.1	Sandstone, very fine grained; no sample; grey; moderately resistant.
S318-1	5m	408.9	Claystone; no sample; dark grey; recessive; sharp lower contact.
S319-1	1.0	413.9	Sandstone; very fine (s-f) grained; poor sorting; very angular (va-a) clasts; 6% dark minerals, 4% carbonaceous material; dark grey, weathering grey; resistant.
S320-1	0.6	414.9	Siltstone; c-vf; poor sorting; 3% dark minerals; dark grey, weathering grey; moderately resistant; sharp lower contact.
S321-1	0.5	415.3	Sandstone, very fine (s-vf) grained; poor sorting; angular (a-sa) clasts; 10% dark minerals, 4% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
S322-1	0.55	415.9	Siltstone; c-vf; poor sorting; 12% dark minerals, 8% carbonaceous material; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S323-1	2.0	417.1	Siltstone; c-vf; poor sorting; 5% dark minerals, 2% carbonaceous material; occasional plant remains; dark green grey, weathering grey; resistant; sharp lower contact.
S324-1	1.0	418.1	Claystone; c-s; poor sorting; 10% dark minerals, 9% carbonaceous material; 3mm laminations; bioturbated; dark green grey, weathering grey; resistant; sharp lower contact.
S325-1	1.5	420.5	Siltstone; c-vf; poor sorting; 7% dark minerals, 4% carbonaceous material; dark grey, weathering green grey; resistant; sharp lower contact.
S326-1	1.8	421.3	Claystone; c-s; moderate sorting; 3% dark minerals, 1% carbonaceous material; abundant plant remains; dark grey, weathering grey; resistant; sharp lower contact.
S327-1	0.35	422.5	Sandstone, very fine (s-f) grained; moderate sorting; angular (va-sa) clasts; 6% dark minerals, 1% carbonaceous material; olive grey, weathering grey; resistant; sharp lower contact.
S328-1	0.25	422.8	Claystone; c-s; moderate sorting; 2% dark minerals, 0% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.
S329-1	0.1	423.0	Siltstone; c-vf; poor sorting; subangular (a-sr) clasts; 5% dark minerals, 2% carbonaceous material; medium grey, weathering grey; moderately resistant; sharp lower contact.

Sample Number	Thickness (metres)	Position (metres from base)	Description
S330-1	0.1	423.1	Claystone; c-s; moderate sorting; medium grey, weathering grey; recessive; sharp lower contact.
S331-1	0.35	423.4	Sandstone, very fine (s-f) grained; moderate sorting; angular (va-sa) clasts; 5% dark minerals, 2% carbonaceous material.
S332-1	0.88	424.1	Claystone; well sorted; dark green grey, weathering green grey; recessive; sharp lower contact.
S333-1	1.1	424.9	Siltstone; s-vf; well sorted; angular (va-sa) clasts; 1% dark minerals, 0% carbonaceous material; mud clasts; dark green grey, weathering green grey; resistant; sharp lower contact.
	6.0	430.9	Covered.
S334-1	1.6	433.5	Claystone; no sample; red and green; recessive.
S335-1	2.7	435.1	Siltstone; c-s; poor sorting; 7% dark minerals, 3% carbonaceous material; mud clasts; dark grey, weathering grey; resistant; sharp lower contact.
S336-1	1.45	436.9	Claystone; well sorted; 0% dark minerals, 0% carbonaceous material; mottled red and green; moderately resistant; sharp lower contact.
S337-1	0.45	437.5	Siltstone; c-vf; moderate sorting; subangular (a-sr) clasts; 3% dark minerals, 1% carbonaceous material; banded red and green; moderately resistant; sharp lower contact.
S338-1	1.25	437.9	Claystone; c-s; poor sorting; 5% dark minerals, 2% carbonaceous material; red and green, weathering red; moderately resistant; sharp lower contact.
S339-1	0.4	439.2	Siltstone; no sample; green; moderately resistant; sharp lower contact.
S340-1	0.25	439.5	Siltstone; c-f; poor sorting; bioturbated; red and green, weathering maroon; moderately resistant; sharp lower contact.
S341-1	0.85	440.1	Claystone; c-s; poor sorting; 0% dark minerals, 0% carbonaceous material; bioturbated; faintly red and green, weathering grey; moderately resistant; sharp lower contact.
S342-1	2.0	441.3	Claystone; c-f; poor sorting; 0% carbonaceous material; mud clasts; olive grey, weathering grey; recessive; sharp lower contact.
S343-1	0.2	442.5	Siltstone; c-s; moderate sorting; 0% dark minerals, 0% carbonaceous material; mud clasts; olive grey, weathering grey.
S344-1	0.3	442.7	Claystone; poor sorting; mud clasts; red and green, weathering red and grey; recessive; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S345-1	0.8	443.4	Claystone; c-f; poor sorting; bioturbated; olive grey, weathering grey; moderately resistant; sharp lower contact.
S346-1	0.4	443.9	Claystone; c-vf; poor sorting; 5% dark minerals, 2% carbonaceous material; olive grey, weathering red; recessive; sharp lower contact.
S347-1	0.5	444.3	Siltstone; c-vf; poor sorting; dark grey, weathering grey; moderately resistant; sharp lower contact.
S348-1	0.2	444.7	Claystone; c-s; moderate sorting; occasional plant remains; dark green grey, weathering red and green; recessive; sharp lower contact.
S349-1	0.25	444.9	Siltstone; no sample; grey; recessive; sharp lower contact.
S350-1	0.20	445.2	Claystone; well sorted; 0% carbonaceous material; dark grey, weathering grey; recessive; sharp lower contact.
S351-1	0.15	445.3	Siltstone; c-vf; poor sorting; angular (va-sa) clasts; 0% dark minerals, 0% carbonaceous material; bioturbated; dark green grey, weathering grey; recessive; sharp lower contact.
S352-1	0.55	445.8	Claystone; well sorted; 0% carbonaceous material; dark grey, weathering grey; recessive; sharp lower contact.
S353-1	0.1	446.0	Sandstone, very fine (s-f) grained; moderate sorting; angular (va-sa) clasts; 5% dark minerals, 0% carbonaceous material; dark grey, weathering grey; resistant; sharp lower contact.
S354-1	0.1	446.1	Claystone; moderate sorting; 5% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.
S355-1	2.6	447.7	Siltstone; c-vf; poor sorting; angular (va-sa) clasts; 0% carbonaceous material; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S356-1	0.9	449.1	Sandstone, very fine (c-f) grained; poor sorting; angular (va-sa) clasts; 1% dark minerals, 0% carbonaceous material; medium grey, weathering grey; resistant; sharp lower contact.
S357-1	0.4	449.9	Claystone; moderate sorting; 0% carbonaceous material; dark grey, weathering grey; resistant; sharp lower contact.
S358-1	0.55	450.3	Same as S357-1.
S359-1	0.2	450.7	Siltstone; c-f; poor sorting; angular (va-a) clasts; 2% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S360-1	0.3	451.0	Claystone; moderate sorting; 8% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.
S361-1	0.25	451.2	Same as S360-1.
S362-1	0.2	451.4	Same as S360-1.
S363-1	1.2	452.1	Claystone; c-s; poor sorting; bioturbated; slickensides; medium grey, weathered grey; recessive; sharp lower contact.
S364-1	0.3	451.9	Siltstone; c-s; poor sorting; mud clasts; dark green grey, weathering grey; sharp lower contact.
S365-1	0.65	453.4	Siltstone; c-vf; poor sorting; 0% dark minerals, 0% carbonaceous material; mud clasts; dark green grey, weathering grey; resistant; sharp lower contact.
S366-1	1.3	454.1	Claystone; well sorted; occasional plant remains; dark green grey, weathering grey; recessive; sharp lower contact.
S367-1	0.9	455.4	Claystone; moderate sorting; occasional transported calcareous algal balls; olive grey, weathering grey; resistant; sharp lower contact.
S368-1	0.2	456.0	Claystone; moderate sorting; mud clasts; dark grey, weathering grey; recessive; sharp lower contact.
S369-1	0.2	456.1	Same as S368-1.
S370-1	0.18	456.4	Same as S371-1.
S371-1	1.5	456.9	Claystone; well sorted; 0% carbonaceous material; bioturbated; dark grey, weathering grey; moderately resistant; sharp lower contact.
S372-1	1.2	458.9	Same as S371-1.
S373-1	0.7	459.6	Siltstone; well sorted; 0% dark minerals, 0% carbonaceous material; mud clasts; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S374-1	2.2	461.5	Claystone; well sorted; 0% dark minerals, 0% carbonaceous material; medium grey, weathering grey; moderately resistant; sharp lower contact.
S375-1	0.3	462.2	Siltstone; c-s; poor sorting; 2% dark minerals, 0% carbonaceous material; mud clasts; medium grey, weathering grey; moderately resistant; sharp lower contact.
S376-1	0.15	462.5	Claystone; moderately sorted; 0% dark minerals, 0% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.
S377-1	0.1	462.6	Same as S376-1.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
S378-1	0.85	463.2	Claystone; c-s; poor sorting; 3% dark minerals, 2% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.
S379-1	0.25	463.6	Claystone; c-s; poor sorting; 0% carbonaceous material; bioturbated; dark green grey, weathering green grey.
S380-1	1.0	463.4	Claystone; well sorted; mud clasts; medium grey, weathering grey; recessive; sharp lower contact.
S381-1	0.45	464.2	Same as S380-1.
	1.0	465.2	Covered.
S382-1	1.8	466.5	Sandstone, very fine (s-f) grained; moderate sorting; angular (va-sr) clasts; 15% dark minerals, 5% carbonaceous material; small trough cross-beds; medium grey, weathering grey; moderately resistant.
S383-1	0.35	467.2	Siltstone; c-vf; poor sorting; angular (va-sa) clasts; 3% dark minerals, 1% carbonaceous material; mud clasts; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S384-1	0.4	467.6	Claystone; c-s; moderate sorting; 0% carbonaceous material; dark grey, weathering grey; recessive; sharp lower contact.
S385-1	1.3	468.5	Claystone; well sorted; 0% carbonaceous material; light grey, weathering grey; moderately resistant; sharp lower contact.
S386-1	4.0	472.1	Claystone; c-s; moderate sorting; 0% carbonaceous material; bioturbated; medium grey, weathering grey; moderately resistant; sharp lower contact.
S387-1	1.5	474.1	Sandstone, very fine(s-f) grained; poor sorting; angular (va-sa) clasts; 10% dark minerals, 3% carbonaceous material; mud clasts; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S388-1	4.0	476.6	Claystone; c-s; moderate sorting; 0% carbonaceous material; bioturbated; light grey, weathering grey; recessive; sharp lower contact.
S389-1	2.18	479.7	Same as S388-1.
S390-1	0.25	481.0	Claystone; c-s; poor sorting; 0% carbonaceous material; mud clasts; medium grey, weathering grey; recessive; sharp lower contact.
S391-1	0.25	481.2	Sandstone; very fine grained; well sorted; sub-angular (a-sa) clasts; 10% dark minerals, 0% carbonaceous material; medium grey, weathering grey; moderately resistant; sharp lower contact.
S392-1	2.6	482.8	Claystone; well sorted; 0% dark minerals, 0% carbonaceous material; bioturbated; medium grey, weathering grey; sharp lower contact.

Sample Number	Thick- ness (metres)	Position (metres from base)	Description
S393-1	0.35	484.1	Claystone; c-s; moderate sorting; 1mm laminations; bioturbated; dark grey, weathering grey; recessive; sharp lower contact.
S394-1	0.7	484.8	Siltstone; c-f; poor sorting; 8% dark minerals, 3% carbonaceous material; 6mm laminations; olive grey, weathering grey; resistant; sharp lower contact.
S395-1	0.25	485.1	Claystone; c-s; moderate sorting; 10% dark minerals, 5% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.
S396-1	0.4	485.4	Sandstone, very fine (s-f) grained; poor sorting; subangular (a-sa) clasts; 10% dark minerals, 2% carbonaceous material; medium grey, weathering grey; resistant; sharp lower contact.
S397-1	0.25	485.7	Claystone; c-s; moderate sorting; 0% carbonaceous material; medium grey, weathering grey; recessive; sharp lower contact.
S398-1	0.85	486.3	Sandstone, very fine (s-f) grained; poor sorting; 0% carbonaceous material; bioturbated; dark green grey, weathering grey; moderately resistant; sharp lower contact.
S399-1	1.0	486.9	Claystone; well sorted; medium; grey, weathering grey; moderately resistant; gradational lower contact.
S400-1	1.45	488.1	Claystone; well sorted; bioturbated; dark green grey, weathering grey; recessive; sharp lower contact.
S401-1	2.6	490.7	Siltstone; c-vf; moderate sorting; 3% dark minerals, 1% carbonaceous material; dark green grey, weathering grey; recessive; gradational lower contact.
S402-1	1.3	492.1	Sandstone, very fine (c-f) grained; poor sorting; very angular (va-sa) clasts; 10% dark minerals, 3% carbonaceous material; dark green grey, weathering green grey; recessive; gradational lower contact.
S403-1	1.6	494.1	Siltstone; c-s; moderate sorting; 2% dark minerals, 0% carbonaceous material; large calcareous concretions; bioturbated; dark green grey, weathering green grey; recessive; sharp lower contact.
S404-1	1.4	495.1	Same as S403-1.
S405-1	1.5	496.5	Sandstone, very fine (s-f) grained; moderate sorting; angular (va-sa) clasts; 5% dark minerals, 2% carbonaceous material; green grey, weathering brown green; recessive; sharp lower contact.
			Zone of faulting where the Mill Creek Formation is thrust over the Blackstone Formation.

Top of Mill Creek Formation

Total thickness is 89 metres

BURNT TIMBER CREEK MEASURED SECTION

Beaver Mines Formation

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
B1-1	0.8	0.4	Sandstone, fine-grained (vf-m); poorly sorted; angular clasts (va-sa); 15% dark mineral, 8% carbonaceous materia; dark green grey, weathering grey; resistant; sharp lower contact.
B2-1	2.0	1.9	Sandstone, fine-grained (vf-m); moderate sorting; subangular clasts (a-sa); 10% dark minerals, 5% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
B3-1	1.0	3.4	Sandstone, fine-grained (silt-fine); poorly sorted; subangular clasts (a-sr); 11% dark minerals, 8% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
B4-1	1.0	4.4	Sandstone, fine-grained (silt-med); poorly sorted; angular clasts (a-sa); 8% dark minerals, 5% carbonaceous material; dark green grey, weathering grey; resistant, sharp lower contact.
B5-1	1.5	5.8	Sandstone, very fine-grained (vf-f); moderate sorting; angular clasts (va-a); 10% dark minerals, 2% carbonaceous material; occasional plant fragments; olive grey, weathering brown grey; resistant; sharp lower contact.
B6-1	0.9	6.9	Sandstone, medium grained (vf-m); poorly sorted; subangular clasts (a-sa); 5% dark minerals, 1% carbonaceous material; dark green grey, weathering green grey; resistant; sharp lower contact.
B7-1	2.0	8.9	Sandstone, very fine (s-f); poorly sorted; subangular clasts (a-sa); 15% dark mineral, 2% carbonaceous material; plant fragments; dark green grey, weathering dark grey; resistant; gradational lower contact.
B7-2	1.3	9.9	Siltstone; (c-vf); poorly sorted; very angular clasts (va-a); 10% carbonaceous material; plant fragments; olive black, weathering dark grey; resistant; gradational lower contact.
B8-1	0.5	10.7	Sandstone, very fine-grained (s-f); poorly sorted; angular clasts (va-sa); 5% dark minerals, 1% carbonaceous material; dark green grey, weathering light grey; resistant; sharp lower contact.
B9-1	1.2	11.9	Sandstone, medium-grained (vf-m); moderate sorting; subangular clasts (a-sa); 6% dark minerals, 0% carbonaceous material; green grey, weathering green grey; resistant; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
B10-1	2.0	13.2	Siltstone, (c-vf); poorly sorted; angular clasts (va-sa); 5% carbonaceous material; olive black, weathering dark grey; moderate resistance; gradational lower contact.
B11-1	1.0	14.8	Siltstone, (c-2); moderate sorting; 2% carbonaceous material; dark grey, weathering dark grey; recessive; gradational lower contact.
B12-1	1.4	16.1	Sandstone, fine-grained (vf-f); moderate sorting; subangular clasts (a-sa); 5% dark minerals, 1% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
B13-1	0.85	17.2	Siltstone, (c-s); moderate sorting; 5% carbonaceous material; dark grey, weathering grey; recessive; sharp lower contact.
B14-1	2.0	18.4	Sandstone, very fine-grained (s-f); poor sorting; angular clasts (va-sa); 12% dark minerals, 3% carbonaceous material; dark green grey, weathering grey; moderate resistance; sharp lower contact.
B15-1	2.3	20.7	Claystone, (c-s); moderate sorting; 3% carbonaceous material; dark grey, weathering grey; recessive; gradational lower contact.
B16-1	0.95	22.3	Sandstone; very fine-grained (vf-f); moderate sorting; angular clasts (va-sa); 8% dark minerals, 1% carbonaceous material; dark green grey, weathering grey; moderate resistance; sharp lower contact.
B17-1	0.25	22.8	Claystone; silty; well sorted; 1% carbonaceous material; dark grey, weathering dark grey; recessive; sharp lower contact.
B18-1	0.65	23.4	Sandstone, very fine-grained (c-f); poorly sorted; 3% carbonaceous material; small scale cross-beds; dark grey, weathering brown grey; resistant; sharp lower contact.
B19-1	1.2	24.1	Claystone; silty; moderate sorting; 1% carbonaceous material; concretions; dark grey, weathering dark grey; recessive; sharp lower contact.
B20-1	1.1	25.2	Claystone; silty; poor sorting; 4$ carbonaceous material; laminated; olive grey, weathering grey; resistant; sharp lower contact.
B21-1	0.15	26.0	Claystone; well sorted; dark green-grey, weathering green grey; sharp lower contact; recessive.
B22-1	0.8	26.4	Siltstone; c-s; poor sorting; dark green grey, weathering green grey; moderate resistance; sharp lower contact.
B23-1	0.5	27.1	Claystone; silty; poorly sorted; dark green grey, weathering green grey; recessive; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
B24-1	0.2	27.5	Claystone; silty; poorly sorted; dark green grey, weathering green grey; recessive; sharp lower contact.
B25-1	0.2	27.7	Siltstone; c-s; poorly sorted; dark grey, weathering grey; recessive; sharp lower contact.
B26-1	0.1	27.8	Siltstone; c-s; poorly sorted; dark grey, weathering grey; recessive; sharp lower contact.
B27-1	0.1	27.9	Claystone; well sorted; dark green grey, weathering green; recessive; gradational lower contact.
B28-1	0.35	28.2	Sandstone; very fine-grained (s-f); moderate sorting; 5% dark minerals, 0% carbonaceous material; mud pellets; dark green grey, weathering brown grey; moderate resistance; sharp lower contact.
B29-1	0.6	28.7	Claystone; well sorted; 1% carbonaceous material; bioturbated; dark green grey, weathering green; recessive; sharp lower contact; thins laterally into B30-1.
B30-1	0.8	29.5	Sandstone; very fine (s-vf); moderate sorting; angular clasts (va-sa); 4% dark minerals, 0% carbonaceous material; olive black, weathering grey; resistant; sharp lower contact.
	1.6	31.3	Covered.
B31-1	0.9	31.5	Siltstone; c-vf; moderate sorting; 15% dark minerals, 8% carbonaceous material; 2mm laminations; dark green grey, weathering green grey; recessive.
B32-1	0.75	32.5	Siltstone; c-s; moderate sorting; 20% dark minerals, 10% carbonaceous material; dark grey, weathering grey; moderate resistance; sharp lower contact.
B33-1	0.3	33.1	Claystone; silty; moderate sorting; dark grey, weathering dark grey; recessive; sharp lower contact.
B34-1	0.6	33.6	Sandstone; very fine-grained (s-vf); poor sorting; angular (va-a); 15% dark minerals, 7% carbonaceous material; 1 mm laminations; dark green grey, weathering grey; moderate resistance; sharp lower contact.
B35-1	0.2	34.1	Siltstone; c-vf; moderate sorting; angular clasts (va-sa); dark green grey, weathering brown grey; sharp lower contact; moderate resistance.
B36-1	0.55	34.4	Siltstone; c-vf; moderate sorting; angular clasts (va-sa); dark green grey, weathering brown grey; sharp lower contact; moderate resistance.
B37-1	0.1	34.8	Claystone; well sorted; dark grey, weathering dark grey; recessive; sharp lower contact.
B38-1	0.65	35.1	Siltstone; c-vf; moderate sorting; 3% dark minerals, 1% carbonaceous material; dark green grey, weathering green grey; moderately resistant; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
B39-1	0.75	35.8	Siltstone; c-s; moderate sorting; 4% dark minerals, 3% carbonaceous material; dark green grey, weathering grey; 4mm laminations; moderate resistance; sharp lower contact.
B40-1	1.0	36.9	Sandstone; very fine-grained (s-vf); poorly sorted; angular clasts (a-sa); 10% dark minerals, 5% carbonaceous material; dark green grey, weathering brown grey; resistant; sharp lower contact.
B41-1	1.2	37.5	Sandstone, medium-grained (f-m); moderate sorting; very angular clasts (va-a); 20% dark minerals, 10% carbonaceous material; abundant plant fragments; dark green grey, weathering brown; resistant; gradational lower contact.
B42-1	0.1	38.4	Sandstone, fine-grained (vf-f); moderate sorting; 8% carbonaceous material; occasional plant fragments; dark green grey, weathering grey; recessive; sharp lower contact.
B43-1	0.15	38.4	Siltstone; c-s; moderate sorting; rare plant fragments; dark green grey, weathering grey; gradational lower contact; recessive.
B44-1	0.2	38.6	Claystone; silty; moderate sorting; dark green grey, weathering grey; recessive; gradational lower contact.
B45-1	1.1	39.2	Siltstone; c-vf; poor sorting; 12% carbonaceous material; rippling; dark green grey, weathering brown grey; resistant; sharp lower contact.
B46-1	0.15	40.0	Sandstone; very fine-grained (s-vf); moderate sorting; angular clasts (a-sa); 6% dark minerals, 2% carbonaceous material; small scale cross-beds; load casts; dark green grey, weathering brown grey; resistant; sharp lower contact.
B47-1	0.1	40.1	Siltstone; c-vf; moderate sorting; 7% carbonaceous material; dark grey, weathering grey; moderately resistant; sharp lower contact.
B48-1	0.1	40.2	Claystone; moderate sorting; 10% carbonaceous material; small cross-beds; dark grey, weathering grey; sharp lower contact.
B49-1	0.2	40.3	Claystone; moderate sorting; 10% carbonaceous material; saml1 cross-beds; dark grey, weathering grey; sharp lower contact.
B50-1	0.3	40.6	Claystone; moderate sorting; 10% carbonaceous material; small cross-beds; dark grey, weathering grey; sharp lower contact.
B51-1	0.6	41.1	Sandstone; very fine-grained (s-f); poorly sorted; angular clasts (va-a); 8% dark minerals, 2% carbonaceous material; small cross-beds; dark green grey, weathering green grey; resistant; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
B52-1	0.1	41.4	Claystone; silty; moderate sorting; dark green grey, weathering grey; recessive; sharp lower contact.
B53-1	0.1	41.5	Sandstone; fine-grained (s-f); poor sorting; angular clasts (va-sa); 5% dark minerals, 3% carbonaceous material; occasional plant fragments; dark green grey; weathering brown grey; moderately resistant; sharp lower contact.
B54-1	0.25	41.6	Sandstone; fine-grained (s-f); poor sorting; angular clasts (va-sa); 5% dark minerals, 3% carbonaceous material; occasional plant fragments; dark green grey; weathering brown grey; moderately resistant; sharp lower contact.
B55-1	1.2	42.3	Siltstone; c-s; poor sorting; 10% carbonaceous material; small cross-beds; dark grey, weathering grey; resistant; gradational lower base.
B56-1	0.1	43.0	Claystone; well sorted; dark grey, weathering grey; recessive; sharp lower contact.
B57-1	1.45	44.1	Sandstone, very fine-grained (s-vf); moderate sorting; very angular clasts (va-a); 10% dark minerals, 2% carbonaceous material; trough cross-beds; dark green grey, weathering grey; resistant; sharp lower contact.
B58-1	0.25	44.6	Sandstone, very fine-grained (s-vf); moderate sorting; very angular clasts (va-a); 10% dark minerals, 2% carbonaceous material; trough cross-beds; dark green grey, weathering grey; resistant; sharp lower contact.
B59-1	0.55	45.2	Sandstone, medium grained (f-m); moderate sorting; angular clasts (va-sa); 8% dark minerals, 1% carbonaceous material; dark green grey, weathering green grey; resistant; sharp lower contact.
B60-1	0.2	45.4	Sandstone, very fine-grained (s-f); poor sorting; angular clasts (a-sa); 5% carbonaceous material, dark green grey, weathering grey; moderatly resistant; gradational lower contact.
B61-1	0.3	45.7	Siltstone; c-s; poorly sorted; 5% carbonaceous material; dark grey, weathering grey; recessive; gradational lower contact.
B62-1	0.45	46.2	Sandstone; very fine-grained (s-f); poorly sorted; very angular clasts (va-a); 5% carbonaceous material; dark green grey, weathering grey; moderatly resistant; sharp lower contact.
B63-1	0.25	46.4	Same as B64-1.
B64-1	0.35	46.7	Claystone; silty; moderate sorting; dark green grey, weathering grey; recessive; sharp lower contact.
B65-1	0.4	47.1	Siltstone; c-vf; poor sorting; angular clasts (va-a); 3% carbonaceous material; dark green grey, weathering brown grey; recessive; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
	2.5	49.75	Covered
B66-1	2.0	47.7	Sandstone; medium grained (f-m); moderate sorting; angular clasts (a-sa); 10% dark minerals, 1% carbonaceous material; large trough cross-beds; green grey, weathering grey; moderately resistant.
B66-2	2.0	49.7	Same as B66-1
B66-3	1.5	53.7	Sandstone, fine-grained (f-m); moderate sorting; angular clasts (a-sa); 8% dark minerals, 1% carbonaceous material; large trough cross-beds; moderately resistant; green grey, weathering grey; gradational lower contact.
B67-1	2.0	55.2	Sandstone; fine-grained (vf-f); poorly sorted; angular clasts (va-a); 15% dark minerals, 5% carbonaceous material; dark green grey, weathering brown grey; resistant; sharp lower contact.
B67-2	3.0	57.7	Same as B67-1.
B68-1	2.0	61.2	Sandstone; fine-grained; well sorted; angular clasts (a-sa); 8% dark minerals, 3% carbonaceous material; dark green grey, weathering grey; resistant; gradational lower contact.
B69-1	2.0	62.4	Sandstone; fine-grained (vf-f); moderately sorted; angular clasts (a-sa); 8% dark minerals, 2% carbonaceous material; dark green grey, weathering grey; resistant; gradational lower contact.
B69-2	1.8	64.2	Sandstone; very fine-grained (s-f); poorly sorted; angular clasts (va-a); 6% dark minerals, 3% carbonaceous material; dark green grey, weathering grey; resistant; gradational lower contact.
B70-1	0.65	66.1	Same as B69-2.
B71-1	0.3	66.9	Siltstone; c-s; poorly sorted; asummetrical ripple marks; dark green grey, weathering grey; recessive; sharp lower contact.
B72-1	0.3	67.1	Claystone; well sorted; dark grey, weathering grey; recessive; gradational lower contact.
B73-1	0.45	67.5	Sandstone; very fine-grained (c-f); poorly sorted; 5% dark minerals, 1% carbonaceous material; dark green grey, weathering grey; moderately resistant; sharp lower contact.
B74-1	0.1	67.8	Claystone; silty; moderate sorting; dark grey, weathering grey; recessive; sharp lower contact.
	2.0	69.8	Covered
B76-1	2.6	71.4	Same as B74-1
	1.05	73.5	Covered
B78-1	3.3	75.2	Same as B74-1

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
B79-1	0.35	77.1	Sandstone; very fine-grained (c-vf); poor sorting; 6% carbonaceous material; dark green grey, weathering brown grey; moderately resistant; sharp lower contact.
B80-1	1.0	77.6	Sandstone, very fine-grained (vf-f); moderate sorting; angular clasts (va-sa); 8% dark minerals, 2% carbonaceous material; dark green grey, weathering brown grey; moderately resistant; sharp lower contact.
B81-1	2.0	80.5	Sandstone; very fine-grained (s-f); poor sorting; angular clasts (va-sa); 5% dark minerals, 3% carbonaceous material; dark green grey, weathering green grey; moderately resistant; gradational lower contact.
B82-1	0.3	81.7	Siltstone; sandy; moderate sorting; angular clasts (va-a); 5% dark minerals, 3% carbonaceous material; dark grey, weathering grey; resistant; sharp lower contact.
B84-1	2.0	82.8	Claystone; silty; poor sorting; 8% carbonaceous material; moderately resistant; dark green grey, weathering grey; sharp lower contact.
	4.0	87.8	Covered
B85-1	1.5	88.5	Claystone; well sorted; dark grey; weathering dark grey; recessive.
B86-1	1.3	89.9	Sandstone; medium grained (f-m); moderate sorting; angular clasts (a-sa); 6% dark minerals, 4% carbonaceous material; dark green grey, weathering grey; moderately resistant; sharp lower contact.
	1.7	92.3	Covered.
B87-1	1.9	93.5	Claystone; well sorted; dark grey, weathering grey; recessive.
B88-1	0.35	94.5	Sandstone; very fine-grained (s-vf); moderate sorting; angular clasts (va-a); 3% dark minerals, 2% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
B89-1	0.8	95.2	Sandstone, medium grained (f-m); poor sorting; very angular clasts (va-a); 6% dark minerals, 2% carbonaceous material; green grey, weathering green grey; resistant; sharp lower contact.
B90-1	0.2	95.5	Sandstone, very fine-grained (s-f); moderate sorting; very angular clasts (va-a); 4% dark minerals, 2% carbonaceous material; dark green grey, weathering grey; moderately resistant; sharp lower contact.
B91-1	0.75	96.1	Claystone; moderate sorting; occasional plant fragments; dark grey, weathering grey; recessive; sharp lower contact.

Sample Number	Thick- ness (metres)	Position (metres from base)	Description
B92-1	0.45	96.6	Sandstone; fine-grained (vf-f); poor sorting; angular clasts (va-a); 15% dark minerals, 4% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
B93-1	0.1	96.9	Combined with B94-1.
B94-1	1.45	97.5	Sandstone; very fine-grained (s-vf); poor sorting; angular clasts (va-a); 8% dark minerals, 3% carbonaceous material; large trough cross-beds; dark green grey, weathering grey; resistant; sharp lower contact.
B95-1	0.6	98.9	Siltstone; sandy; moderate sorting; very angular clasts (va-a); 7% dark minerals, 3% carbonaceous material; mud clasts; dark green grey, weathering grey; moderately resistant; sharp lower contact.
B96-1	0.3	99.2	Combined with B95-1.
B97-1	1.0	99.8	Sandstone; very fine-grained (s-vf); moderate sorting; very angular clasts (va-a); 10% dark minerals, 2% carbonaceous material; large trough cross-beds; dark green grey, weathering grey; resistant; sharp lower contact.
B98-1	0.4	100.6	Combined with B97-1.
B99-1	0.4	100.9	Sandstone; very fine-grained (vf-f); moderate sorting; angular clasts (va-sa); 10% dark minerals, 6% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
B100-1	0.2	101.2	Claystone; silty; poor sorting; dark grey, weathering grey; recessive; sharp lower contact.
B101-1	1.3	101.8	Sandstone; very fine-grained (s-f); moderate sorting; angular clasts (va-sa); 15% dark minerals, 5% carbonaceous material; dark green grey, weathering green grey; resistant; sharp lower contact.
B102-1	0.5	102.9	Claystone; well sorted; dark grey, weathering grey; recessive; sharp lower contact.
B103-1	2.0	104.5	Siltstone; c-vf; moderate sorting; very angular clasts (va-a); 5% dark minerals, 2% carbonaceous material; dark green grey, weathering grey; moderately resistant; sharp lower contact.
	0.95	106.0	Covered.
B101-1	0.85	106.2	Sandstone; medium grained (f-m); moderate sorting; angular clasts (a-sa); 10% dark minerals, 4% carbonaceous material; resistant; dark green grey, weathering green grey; sharp lower contact.
B105-1	0.3	107.1	Sandstone; very fine-grained (s-f); poor sorting; angular clasts (va-sa); 5% dark minerals, 3% carbonaceous material; occasional plant fragments; dark green grey, weathering grey; moderately resistant; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
B106-1	0.2	107.3	Combined with B105-1.
	1.0	108.3	Covered.
B107-1	1.0	108.8	Sandstone; very fine-grained (c-f); poor sorting; angular clasts (a-sa); 5% dark minerals, 3% carbonaceous material; mud clasts; dark green grey, weathering green; recessive.
	1.8	111.15	Covered.
B108-1	0.25	111.3	Siltstone; c-s; moderate sorting; occasional plant fragments; dark green grey, weathering green; recessive.
B109-1	0.5	111.7	Claystone; silty; poor sorting; 5% dark minerals; recessive; dark green grey, weathering green; gradational lower contact.
B110-1	0.2	112.1	Siltstone, c-s; poor sorting; dark green grey, weathering green; recessive; gradational lower contact.
	1.1	113.2	Covered.
B111-1	0.7	113.5	Claystone; well sorted; bioturbated; dark grey, weathering grey; recessive.
B112-1	0.3	114.1	Siltstone; c-f; poor sorting; angular clasts (va-sa); 5% dark minerals, 2% carbonaceous material; dark green grey, weathering green grey; recessive; sharp lower contact.
B113-1	1.8	115.2	Claystone; well sorted; bioturbated; dark grey, weathering grey; recessive.
B114-1	1.0	116.5	Sandstone; coarse grained (m-vcr); moderate sorting; angular clasts (a-sa); 8% dark minerals, 1% carbonaceous material; olive grey, weathering green grey; resistant.
B115-1	3.0	119.0	Claystone; silty; moderate sorting; dark grey, weathering grey; recessive; sharp lower contact.
B116-1	1.0	120.5	Sandstone; coarse grained (m-vcr); moderate sorting; angular clasts (a-sa); 5% dark minerals, 0% carbonaceous material; large trough cross-beds; olive grey, weathering green grey; resistant; sharp lower contact.
B117-1	1.9	122.1	Sandstone; coarse grained, pebbly; poor sorting; angular clasts (a-sa); 10% dark minerals, 3% carbonaceous material; olive grey, weathering green grey; resistant; sharp lower contact.
B118-1	0.5	123.2	Same as B117-1
B119-1	2.0	123.8	Sandstone; medium grained; moderate sorting; subangular clasts (a-sa); 15% dark minerals, 2% carbonaceous material; olive grey, weathering green grey; resistant; sharp lower contact.
B120-1	1.0	125.0	Same as B119-1.

Sample Number	Thick- ness (metres)	Position (metres from base)	Description
B120-2	1.0	126.8	Sandstone; coarse grained (m-cr); moderate sorting; subangular clast (a-sa); 10% dark minerals, 0% carbonaceous material; olive grey, weathering grey; resistant; sharp lower contact.
B121-1	0.4	127.6	Sandstone; coarse grained (f-cr); poor sorting; subangular clasts (a-sa); 8% dark minerals, 1% carbonaceous material; mud clasts; olive grey, weathering green grey; resistant; sharp lower contact.
B122-1	1.2	128.5	Sandstone; very coarse grained (m-pebbly); same as B121-1.
B123-1	0.4	129.2	Sandstone; same as B121-1.
B124-1	0.7	129.8	Sandstone; coarse grained (m-vcr); poor sorting; subangular clasts (a-sa); abundant plant remains; 10% dark minerals, 2% carbonaceous material; mud clasts; olive grey, weathering green grey; resistant; sharp lower contact.
B125-1	1.0	130.8	Sandstone; fine grained (f-m); poor sorting; angular clasts (a-sr); 15% dark minerals, 4% carbonaceous material; mud clasts; olive grey, weathering green grey; resistant; sharp lower contact.
B126-1	2.0	131.1	Sandstone; medium grained (f-cr); poor sorting; subangular clasts (a-sr); 10% dark minerals, 4% carbonaceous material; olive grey, weathering green grey; resistant; sharp lower contact.
B126-2	0.8	133.1	Same as B126-1.
B127-1	2.0	133.9	Sandstone; medium grained (f-m); moderate sorting; subangular clasts (a-sa); 15% dark minerals, 8% carbonaceous material; abundant plant remains; resistant; sharp lower contact.
B127-2	2.0	135.9	Sandstone; medium grained (m-cr); poor sorting; angular clasts (a-sa); 10% dark minerals, 2% carbonaceous material; dark green grey, weathering green grey; resistant; gradational lower contact.
B127-3	2.0	137.9	Same as B127-2.
B127-4	2.0	139.2	Sandstone; medium grained (f-m); moderate sorting; subangular clasts (a-sr); 8% dark minerals, 1% carbonaceous material; olive grey, weathering green grey; resistant; gradational lower contact.
B127-5	2.0	141.9	Sandstone; medium grained (f-m); poor sorting; subangular clasts (a-sa); 15% dark minerals, 3% carbonaceous material; green grey, weathering green grey; resistant, gradational lower contact.
B127-6	2.0	143.9	Sandstone; medium grained (f-m); poor sorting; angular clasts (a-sa); 15% dark minerals, 1% carbonaceous material; dark green grey, weathering green grey; resistant; gradational lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
B127-7	2.0	145.9	Same as B127-6.
B127-8	2.0	147.9	Sandstone; fine grained (f-m); poor sorting; angular clasts (va-sa); 15% dark minerals, 2% carbonaceous material; green grey, weathering green grey; resistant; gradational lower contact.
B128-1	1.1	150.5	Sandstone; medium grained (f-m); poor sorting; angular clasts (a-sa); 6% dark minerals, 2% carbonaceous material; large trough cross-beds; dark green grey, weathering green grey; resistant; sharp lower contact.
B129-1	0.05	151.0	Siltstone; c-f; poor sorting; 3% carbonaceous material; asymmetrical ripple marks; dark grey, weathering grey; recessive; sharp lower contact.
B130-1	0.5	151.3	Claystone; fissile; well sorted; dark grey, weathering grey; recessive; sharp lower contact.
B131-1	0.2	151.6	Sandstone; fine grained (vf-f); poor sorting; angular clasts (va-sa); 10% dark minerals, 2% carbonaceous material; large trough cross-beds; dark green grey, weathering green grey; resistant; erosional lower contact; erosional relief on base of a few feet.
B131-2	2.0	153.5	Sandstone; gradational lower contact; same as B131-1.
B131-3	2.0	155.5	Same as B-131-2.
B132-1	1.5	156.8	Sandstone; medium grained (f-m); poor sorting; subangular clasts (a-sr); 8% dark minerals, 0% carbonaceous material; large trough cross-beds; green grey, weathering green grey; resistant; sharp lower contact.
B133-1	0.7	157.4	Sandstone; very fine grained (s-f); poor sorting; angular clasts (va-sa); 4% dark minerals, 2% carbonaceous material; rare plant remains; dark green grey, weathering green grey; moderately resistant; sharp lower contact.
B134-1	0.85	158.4	Siltstone; c-vf; poor sorting; 3% carbonaceous material; dark grey, weathering grey; moderately resistant; gradational lower contact.
B135-1	0.9	159.3	Claystone; silty; moderate sorting; 1 mm laminations; asymmetrical ripples; dark grey, weathering grey; recessive; gradational lower contact.
B136-1	0.3	159.9	Combined with B137-1.
B137-1	0.1	160.1	Siltstone; c-s; moderate sorting; 2% dark minerals, 1% carbonaceous material; dark green grey, weathering green grey; moderately resistant; sharp lower contact.
B138-1	0.45	160.4	Sandstone; very fine grained (s-f); poor sorting; 5% dark minerals, 3% carbonaceous material; angular clasts (va-a); resistant; dark green grey, weathering green grey; sharp lower contact.

Sample Number	Thickness (metres)	Position (metres from base)	Description
B139-1	0.4	160.5	Siltstone; c-s; poor sorting; 3% carbonaceous material; dark grey, weathering brown grey; sharp lower contact; moderately resistant.
B140-1	1.55	161.8	Claystone; silty; moderate sorting; 2% carbonaceous material; dark grey, weathering grey; recessive; sharp lower contact.
B141-1	0.4	162.8	Sandstone; medium grained (f-m); moderate sorting; subangular clasts (a-sa); 7% dark minerals, 1% carbonaceous material; large trough cross-beds; green grey, weathering grey; resistant; sharp lower contact.
B142-1	2.0	162.9	Sandstone; medium grained (f-m); moderate sorting; angular clasts (a-sa); 8% dark minerals, 2% carbonaceous material; large trough cross-beds; resistant; sharp lower contact; green grey, weathering brown grey.
B142-2	1.0	164.9	Same as B142-1.
B143-1	0.2	166.1	Sandstone; medium grained (m-cr); poor sorting; angular clasts (a-sa); 10% dark minerals, 3% carbonaceous material; occasional plant remains; green grey, weathering green grey; resistant; sharp lower contact.
B144-1	1.7	166.9	Sandstone; medium grained (f-cr); poor sorting; angular clasts (va-sa); 5% dark minerals, 3% carbonaceous material; large trough cross-beds; mud clasts; occasional plant remains; green grey, weathering green grey; resistant; sharp lower contact.
B145-1	0.53	168.2	Sandstone; fine grained (vf-m); poor sorting; angular clasts (a-sa); 10% dark minerals, 4% carbonaceous material; small trough cross-beds; occasional plant remains; green grey, weathering green grey; resistant; sharp lower contact.
B146-1	1.1	169.2	Sandstone; medium grained (f-cr); poor sorting; angular clasts (a-sa); 8% dark minerals, 3% carbonaceous material; large trough cross-beds; dark green grey, weathering grey; resistant; sharp lower contact.
B147-1	0.65	169.9	Sandstone; fine grained (vf-f); moderate sorting; subangular clasts (a-sr); 5% dark minerals, 1% carbonaceous material; small trough cross-beds; olive grey, weathering brown grey; resistant; sharp lower contact.
B148-1	2.0	170.1	Sandstone; fine grained (vf-m); poor sorting; angular clasts (a-sa); 8% dark minerals, 4% carbonaceous material; large trough cross-beds; green grey, weathering grey; resistant; sharp lower contact.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
B148-2	1.5	172.1	Sandstone; medium grained (f-m); poor sorting; subangular clasts (a-sa); 10% dark minerals, 4% carbonaceous material; large trough cross-beds; occasional plant remains; dark green grey, weathering grey; resistant; gradational lower contact.
B148-3	0.5	173.9	Sandstone; medium grained (f-m); poor sorting; angular clasts (va-sa); 15% dark minerals, 8% carbonaceous material; small trough cross-beds; resistant; gradational lower contact.
B149-1	0.5	174.3	Sandstone; fine grained (f-m); moderate sorting; angular clasts (a-sa); 6% dark minerals, 0% carbonaceous material; olive grey, weathering grey; resistant; sharp lower contact.
B150-1	2.0	174.6	Sandstone; fine grained (f-m); poor sorting; angular clasts (a-sa); 10% dark minerals, 2% carbonaceous material; green grey, weathering green grey; resistant; sharp lower contact.
B150-2	2.0	176.5	Same as B150-1.
B151-1	2.0	176.9	Sandstone; fine grained (f-m); moderate sorting; angular clasts (a-sa); 10% dark minerals, 3% carbonaceous material; large cross-beds; green grey, weathering grey; resistant; sharp lower contact.
B151-2	0.2	178.9	Same as B151-1.
B152-1	0.9	179.8	Sandstone; very fine grained (s-f); poor sorting; angular clasts (a-sa); 12% dark minerals, 2% carbonaceous material; green grey, weathering grey; resistant; gradational lower contact.
B153-1	0.4	180.2	Siltstone; s-f; poor sorting; angular clasts (va-a); 12% dark minerals, 8% carbonaceous material; 2 mm laminations; dark green grey, weathering grey; recessive; sharp lower contact.
B154-1	2.1	182.5	Claystone; well sorted; asymmetrical ripples; dark grey, weathering grey; recessive; sharp lower contact.
B155-1	0.45	182.8	Combined with B154-1
B156-1	0.8	183.4	Siltstone; c-s; moderate sorting; rare plant remains; dark grey, weathering grey; resistant; gradational lower contact.
B157-1	3.65	186.2	Claystone; well sorted; asymmetrical ripple marks; dark grey, weathering grey; recessive; sharp lower contact.
B158-1	1.0	187.8	Claystone; silty; moderate sorting; 3% carbonaceous material; dark green grey, weathering grey; recessive; sharp lower contact.
B159-1	0.5	188.7	Combined with B158-1.

Sample Number	Thick- ness (metres)	Position (metres from base)	Description
B160-1	0.4	189.2	Siltstone; c-s; moderate sorting; 4% carbonaceous material; dark grey, weathering brown grey; moderately resistant; sharp lower contact.
B161-1	5.15	192.4	Claystone; silty; poor sorting; 2% carbonaceous material; asymmetrical ripple marks; dark green grey, weathering green grey; recessive; sharp lower contact.
B162-1	0.45	194.5	Combined with B161-1.
B163-1	0.5	195.2	Siltstone; c-s; moderate sorting; 6% carbonaceous material; dark green grey, weathering green grey; moderately recessive; sharp lower contact.
B164-1	0.3	195.6	Claystone; well sorted; rare plant remains; dark green grey, weathering green; recessive; sharp lower contact.
B165-1	0.5	196.1	Sandstone; very fine grained (c-vf); poor sorting; dark green grey, weathering green grey; recessive; sharp lower contact.
B166-1	0.1	196.3	Siltstone; c-vf; poor sorting; dark green grey, weathering dark grey; recessive; gradational lower contact.
B167-1	1.0	196.9	Claystone; c-s; moderate sorting; 2% carbonaceous material; dark green grey, weathering dark green; recessive; gradational lower contact.
B168-1	0.2	197.4	Sandstone; very fine grained (s-vf); poor sorting; angular clasts (va-a); 5% dark minerals, 3% carbonaceous material; mud clasts; dark green grey, weathering brown grey; moderately resistant; sharp lower contact.
B169-1	0.34	197.6	Siltstone; c-vf; poor sorting; angular clasts (va-a); 6% dark minerals, 3% carbonaceous material; dark green grey, weathering brown grey; moderately resistant; gradational lower contact.
B170-1	2.0	197.9	Sandstone; medium grained (f-m); moderate sorting; very angular clasts (va-a); 10% dark minerals, 4% carbonaceous material; large trough cross-beds; mud clasts; occasional plant remains; green grey, weathering grey; resistant; sharp lower contact.
B170-2	1.28	199.8	Sandstone; medium grained (f-cr); poor sorting; angular clasts (va-sa); 10% dark minerals, 2% carbonaceous material; large trough cross-beds; occasional plant remains; green grey, weathering grey; resistant; gradational lower contact.
B171-1	0.6	201.5	Sandstone; very fine grained (s-f); poor sorting; angular clasts (a-sa); 10% dark minerals, 6% carbonaceous material; mud clasts; dark green grey, weathering green grey; resistant.
B-171-2	0.55	202.3	Combined with B171-1.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
B173-1	0.1	202.4	Siltstone; c-s; moderate sorting; 5% carbonaceous material; bioturbated; dark green grey, weathering grey; recessive; sharp lower contact.
B174-1	1.7	203.5	Claystone; well sorted; dark green grey, weathering green; recessive; sharp lower contact.
B175-1	0.6	204.3	Sandstone; fine grained (vf-f); moderate sorting; mud clasts; dark green grey, weathering green grey; moderately resistant.
	1.8	206.5	Covered.
B176-1	0.2	206.6	Siltstone; c-s; poor sorting; mud clasts; bioturbation; dark grey, weathering grey; recessive.
B177-1	2.4	208.3	Claystone; moderate sorting; bioturbation; dark green grey, weathering grey; recessive; sharp lower contact.
	1.9	211.0	Covered.
B178-1	0.9	211.5	Siltstone; c-s; 3% carbonaceous material; moderate sorting; dark grey, weathering grey; moderately resistant.
B179-1	0.25	212.1	Combined with B178-1.
B180-1	1.2	212.5	Claystone; well sorted; green, weathering green; moderately resistant; sharp lower contact.
B181-1	0.35	213.6	Claystone; silty; poor sorting; 3% carbonaceous material; bioturbation; dark grey, weathering brown grey; moderately resistant; sharp lower contact.
B182-1	0.15	213.8	Claystone; well sorted; 6% carbonaceous material; 1mm laminations; symmetrical ripples; dark grey, weathering green grey; recessive; sharp lower contact.
B183-1	0.8	214.2	Sandstone; fine grained (vf-m); poor sorting; angular clasts (va-sa); 5% dark minerals, 2% carbonaceous material; large cross-beds; green grey weathering brown grey; resistant; sharp lower contact.
B184-1	0.08	214.7	Siltstone; c-f; poor sorting; 2% carbonaceous material; dark green grey, weathering brown grey; resistant; sharp lower contact.
B185-1	0.05	214.8	Sandstone; fine grained (vf-f); poor sorting; angular clasts (va-a); 12% dark minerals, 4% carbonaceous material; green grey, weathering brown grey; resistant; sharp lower contact.
B186-1	0.6	215.1	Combined with B185-1.
B187-1	0.5	215.7	Claystone; well sorted; rare plant remains; dark green grey, weathering green; moderately resistant; sharp lower contact.
B188-1	1.1	216.1	Same as B187-1.

Sample Number	Thick-ness (metres)	Position (metres from base)	Description
B189-1	1.0	217.5	Claystone; silty; moderate sorting; dark grey, weathering grey; 8% carbonaceous material; recessive; sharp lower contact.
B190-1	1.6	219.2	Same as B189-1.
B191-1	0.25	219.7	Claystone; well sorted; dark green grey, weathering green; recessive; sharp lower contact.
B192-1	1.0	220.4	Claystone; silty; moderate sorting; 5% carbonaceous material; dark green grey, weathering grey; resistant; sharp lower contact.
B193-1	1.0	221.4	Claystone; well sorted; dark green grey; weathering grey; resistant; sharp lower contact.
B194-1	0.85	222.3	Sandstone; very fine grained (s-f); moderate sorting; angular clasts (va-a); 6% dark minerals, 2% carbonaceous material; dark green grey, weathering brown grey; resistant; sharp lower contact.
B195-1	0.4	222.9	Siltstone; c-vf; poor sorting; 3% carbonaceous material; dark green grey, weathering brown grey; sharp lower contact; recessive.
B196-1	0.8	223.4	Sandstone; fine grained (vf-f); poor sorting; angular clasts (va-sa); 7% dark minerals, 3% carbonaceous material; small cross-beds; dark green grey, weathering brown grey; resistant; sharp lower contact.
B197-1	1.45	224.8	Claystone; well sorted; 0% carbonaceous material; green, weathering green; recessive; sharp lower contact.
B198-1	1.7	226.5	Siltstone; c-s; poor sorting; 2% carbonaceous material; mud clasts; dark green grey, weathering brown grey; recessive; gradational lower contact.
B199-1	0.35	227.2	Claystone; well sorted; 0% carbonaceous material; dark green grey, weathering green; recessive; sharp lower contact.
B200-1	0.6	227.5	Siltstone; c-s; poor sorting; 1% carbonaceous material; 1mm laminations; dark green grey, weathering brown grey; moderately resistant; sharp lower contact.
B201-1	0.35	228.2	Claystone; silty; moderate sorting; 2% carbonaceous material; dark green grey, weathering brown grey; moderately resistant; gradational lower contact.
	2.5	230.8	Covered.
B202-1	1.4	231.5	Siltstone; c-s; moderate sorting; 1% carbonaceous material; dark green grey, weathering grey; resistant.
B203-1	0.75	232.5	Claystone; well sorted; dark green grey, weathering grey; recessive; sharp lower contact.

Sample Number	Thick- ness (metres)	Position (metres from base)	Description
B204-1	0.9	233.6	Sandstone; medium grained (f-m); moderate sorting; angular clasts (a-sa)' 5% dark minerals, 5% carbonaceous material; green grey, weathering grey; resistant; sharp lower contact.
B205-1	0.6	234.2	Same as B204-1.
B206-1	0.4	234.4	Sandstone; fine grained; moderate sorting; angular clasts (va-a); 3% dark minerals, 0% carbonaceous material; grey, weathering grey; resistant; sharp lower contact.
B207-1	0.9	235.2	Sandstone; medium grained; poor sorting; angular clasts (a-sa); 5% dark minerals, 1% carbonaceous material; green grey, weathering grey; resistant; sharp lower contact.
B208-1	0.6	236.1	Sandstone; fine grained (vf-f); poor sorting; angular clasts (va-a); 0% carbonaceous material; green grey, weathering grey; recessive; gradational lower contact.
	1.6	237.9	Covered.
B209-1	0.3	238.1	Sandstone; very fine grained (s-m); poor sorting; 4% carbonaceous material; mud clasts; dark grey, weathering grey; moderately resistant.
	Total Thickness		238.2 metres

Blackstone Formation

Dark grey, fissile claystone and minor grey sandstone.

APPENDIX B.

CODED SAMPLE DESCRIPTIONS

GRAIN SIZE
1 clay
2 silt
3 very fine
4 fine
5 medium
6 coarse
7 very coarse
8 2-4 mm.
9 4-64 mm.
0 64 mm.

%CLASTS
0-10, 11-20, 21-30,
31-40, 41-50, 51-60,
61-70, 71-80, 81-90,
91-100

%QTZ quartz
≤10, 11-20, 21-40,
41-80, >80

%CHERT
GR grey
BL black
0-2, 3-5, 6-10,
11-20, 21-40,
>40

%ROCK FRAG
rock fragments
0-2, 3-5, 6-10,
11-20, 21-40,
>40

PYR
pyrite
0-2, 3-5, >5

%CLAY
3-5, 6-10, 11-20,
21-40, 41-80,
>80

HEM
hematite
0-2, 3-5, >5

%CARB
0-2, 3-5,6-10,
11-20, 21-40,
>40

%LM
carbonate
50-75, >75

FOSSIL
ANIM animal
PLAN plant
O absent
R rare
P present
A abundant

BIO
bioturbation

ROUNDNESS
VA very angular
A angular
SA subangular
SR subrounded
R rounded
WR well rounded

SRT
sorting
P poor
M moderate
W well

LAM
laminations

CHA
channelling

RIP
ripple marks
C climbing
A asymmetrical
S symmetrical

LWR CON
lower contact
E erosional
G gradational
S sharp

CON
concretions

COLOUR
WEAT weathered
W white
B brown
GE green
GG green grey
R red
RG red and green

FRES fresh
DG dark grey
G medium grey
LG light grey
GG green grey
R red
GE green
RG red and green

Explanation of the coded sample descriptions for the type section.

SAMPLE NAME
sample number

UNIT THICK METRE
unit thickness in metres

METRE ABOVE BASE
sample position in metres above the base of the section

GRAIN SIZE
1 clay
2 silt
3 very fine
4 fine
5 medium
6 coarse
7 very coarse
8 conglomerate

ROUNDNESS
VA very angular
A angular
SA subangular
SR subrounded
R rounded
WR well rounded

SOR
sorting
P poor
M moderate
W well

%DARK MINERAL
0. 0-1, 1-2, 2-4
4-8, 8-16, 16-30,
>30

%CARB MATER
0, 0-1, 1-2, 2-4
4-8, 8-16, >16

LWR CNT
lower contact
E erosional
S sharp
G gradational

CHA
channelling

LAM
laminations
0-3 mm.
3-10 mm.
>10 mm.

RIP
ripple marks
A asymmetrical
S symmetrical
C climbing

X-BED
cross-bedding
S small
L large
P planar
TA tangential
TR trough

MUD
mud clasts

CON
concretions

FOSS
fossils
A absent
R rare
P present
AB abundant

BIO
bioturbation

COLOUR
FRES fresh
LG light to dark grey
DG dark grey to black
GG green grey
DY dark green grey
RG red and green

WEATH weathered
G grey
GY green grey
RG red and green
B brown

Explanation of the coded sample descriptions for the Sheep River and Burnt Timber Creek sections.

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                                                                                    FOSSIL                         COLOUR
SAMPLE     GRAIN SIZE         %         %         %         %     %     %    %  %  %        % ANIMPLANB ROUNDNESS  SRTLCXBRIPLWRC WEATH  FRESH
NUMBER                      1 CLASTS    QTZ      CHERT      ROCK  CLAY  CARB BIOTMUSCPIPENHLN        1 V   S S   W   AN    CNIC   GG FD LGG F
       1 2 3 4 5 6 7 8 9 0                      OP    BL    FRAG                          ORPAORPAO A A A B R RPMWMASLCASEGSN WBEGFGGGGGFPG
      ||                 ||        ||   ||    ||    ||          ||    ||  ||  || || ||||  ||  |||          || |||||  || |||     ||     |
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  G2-1  1122211111111111111111221111111112222122221111111111111111122111111111111111121112112 2 112111211111112211111111111121111111111211121111121111
  G3-1  1122211111111111111111211111111112222122221111111111111111122111111111111111121112112 2 11211121111112211111111111121111111111211121111111211111
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                                                                                                      FOSSIL                                  COLOUR
SAMPLE      GRAIN SIZE           %          %          %          %      %      %      %  %  %  %  %  % ANIMPLAND ROUNDNESS  SRTLCXBPIPLWRC WEATH  FRESH
NUMBER                         1 CLASTS    QTZ       CHERT      ROCK   CLAY   CARB  BIOTMUSCPYFEHMLM            1 V  S S  W  AH     CNTO  GG FD LGG F
         1 2 3 4 5 6 7 8 9 0                      GR      BL  FRAG                                OPPROPPAO A A A R R RPMWMASLCASEGSN WDYGFGGGGGFG
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                                                                                      POSSIL                                   COLOUR
SAMPLE     GPAIN SIZE         %       %        %        %     %     %   %  %  %     % ANIMPLANB POUNDNESS  SPTLCXBRIPLWPC WEATH  FRESH
NUMBER                      1 CLASTS     QTZ      CHEPT     POCK  CLAY  CAPB BIOTMUSCPYPEHHL7        1 V   S S   W   AH      CXTO   GG PD LGG B
         1 2 3 4 5 6 7 8 9 0                    GP     BL   FPAG                          OPPAORPAO A A A P R PPHWMASLCASFGCN WBEGPGGGGGEPG
        ||                 ||          ||   ||   ||   ||          ||    ||  ||  || || ||||  ||  |||           || |||||  || |||      ||     |
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G144-1  2221111111111111111112211111111100000000000000000000222222000000000000000000000011211121111000000000000121111111111211111111211111112
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                                                                                                          FOSSIL                                     COLOUR
SAMPLE      GRAIN SIZE          %          %          %          %      %      %      %  %  %          % ANIMPLANT ROUNDNESS  SPTLCXBRIPLWEC WEATH  FRESH
NUMBER                        1 CLASTS    QTZ       CHERT      ROCK   CLAY   CARB BIOTMUSCPYRHEM LM          1 V   S S   W   AM       CHTO   GG RD LGG R
          1 2 3 4 5 6 7 8 9 0                     GR     BL   FRAG                                 ORPAORPAC A  A  A  R  R  RPMWPASLCASTGSN WRIGRGGGGWRG
        ||                 ||          ||    ||    ||    ||              ||    ||   ||   ||  ||  | |||   ||   |||              || |||||   || |||        ||     |
G145-1  11122211111111111111222222222112221111111112111122222122211111111122222111111221112111211111122221111121111111111211112111111121 11
G146-1  2221111111111111111122111111110000000000000000000000000022222200000000000000000000112111210000000000012111111111122111112111111 12
G147-1  121121111111111111112222222221122211111111121111222221222111111111222121111111111121112111112222111111211111111112121121111111 2111
G148-1  2221111111111111111122111111110000000000000000000000000022222200000000000000000000112111210000000000012111111111000211111121111 12
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G150-1  2221111111111111111122111111110000000000000000000000000022222200000000000000000000112111210000000000012111111111121211111121111 12
G151-1  2221111111111111111122111111110000000000000000000000000022222200000000000000000000112111210000000000012111111111112111211111121 11
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M99-1   111111122211111111112222222221222111111111121111222221222111111111221111111112111121112111111111222111211111111100011112111111 2111
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M95-1   2221111111111111111121111111110000000000000000000000000022222200000000000000000000112111210000000000112111111111211121111111211 1
M94-1   12221111111111111111222221111122111111111111111122221122222122111112[illegible]11111111111112111210000000000012111111111112111211111121 11
M93-1   2221111111111111111122111111110000000000000000000000000022222200000000000000000000112111210000000000112111111111211112111111121 11
```

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SAMPLE      GRAIN SIZE            %           %          %          %      %     %    %  %  %          FOSSIL                                          COLOUR
NUMBER                          1 CLASTS     QTZ       CHERT       ROCK   CLAY  CARB BIOTMUSCPYRHEHMLN % ANIMPLANB ROUNDNESS  SPTLCXBPIPLWPC WEATH  FRESH
          1 2 3 4 5 6 7 8 9 0                      GR     BL   FRAG                                LN        1 V   S S   W   AH       CNTO   GG RD LGG P
                                                                                                     ONPAOPPAC A A A P R PPKWTASLCASEGSN WBIGPGGGGGPRG
         ||                  ||         ||   ||     ||     ||            ||    ||  ||  || || |||| || |||
                                                                                                                        || |||||  || |||      ||    |
M92-1   12221111111111111111221111111111221111111111111111112222112222211111112221111111111 112111211111000000000000121111111111211112111111112111
M91-1   111112222211111111111222222211112211111111111111111222222222221111111211111111121111 1121112111111111222111112111111111112111121111111112111
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M86-1   222111111111111111112211111111100000000000000000000000000222221000002222200000000 1121112111100000000000001211111111111121111121111112111
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M77-2   111112222111111111111222222222212222112111112111112222211222111222211122212111111111 1121112111112222121111111211111111111121211111111112111
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M74-1   112211111111111111112222222221122211111111111111122221122211122221122212111121111 1121112111111112222111111121111111111121112111111121111
M73-1   221111111111111111112111111111100000000000000000000000000222222111100000000000000 112111211110000000000001211111111111121112111111211111
M72-1   122221111111111111112222222221122211111111111111122211122211122221122212211111111 11211121111000000000000012111111111121112111112111
M71-1   1111112222111111111122222222212222122111112211112222211111111111112111111111111111 1121112111121222221111111212111111111211121111121111
M70-4   11122211111111111111122222222221222211111111111112211111222111222111221111111211111111 1121112111111111122211111211111111111211121111121111
M70-3   11122211111111111111222222222212222111111111111122111112221112222112221111112111111111 1121112111121222221111111121111112111121112111111121111
M70-2   1112221111111111111122222222221222111111111111112211111222111222211222211111111111111 1121112111121222221111111121211111211112111211111121111
M70-1   111222111111111111112222222211222111111111111122211122211122111122111111111111111 1121112111121222221111111112211111211112111211111121111
M69-5   11111122211111111111222222222212222122111111111112222112221112221112221111111111111 1121112111121222221111111121211111211112111211111121111
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M69-3   11112122211111111111222222222212221122211122211122221122211111111121111111111111111 112111211111111122221111112111112111111211121111112111
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M69-1   1111112221111111111122222222212221122211122211122221112221112221112221211111111111 1121112111111111122221111111211112111112111211111112111
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M68-1   111112221111111111111222222222112211211111211111222211122211122211122112111111111111 112111121111111111222111111121111121111211121111121111
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M66-3   1111111222111111111111222222222122221211111221111222211222111121111122111111111111111 11211121111111122221111112111121111121112111111112111
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M65-1   111112222111111111111122222222211222212111112211112221122111122111122111111111111112111 112111211111111222211111112111121111121112111111112111
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M55-1   1222211111111111111111222211111121111221112211112111112222217222111111111122211111211111111 1121111211111111222211111112111111211112111211111121111
M54-1   111112221111111111111122222211111121111100000000000000000000222221000000000000000211000 11211121111000000000000211111111111121111121111112111
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M52-1   11111222211111111111122222221111221121111121111122222122221121111122112111111111111 11211111211000000000000112111111111121121111121111
M51-1   11122221111111111111222222222112211121111121111122222122221121111122112111111111111 112111121111112222111111121111121111121112111112111
M49-1   22111111111111111111121111111110000000000000000000000000022222221111100000000000000 1121111211111111122221111111211111111111211112111121111
M48-1   1112221111111111111112222222222122111211111211111222211222211222221122211111111111111 112111211110000000000001121111111111121111211111211111
M47-1   221111111111111111111211111111100000000000000000000000000222222000000000000000002111 112111121111111122211111111211121111121112111112111
M46-1   111222111111111111111222222221112211121111211111222211222211222211122222111111111111 112111211110000000000001121111111111122112111111121111
M45-1   22111111111111111111121111111111000000000000000000000000222222000000000000000000 1121111211111111122211111121111111111112111211112111
M44-1   2221111111111111111112211111111100000000000000000000000002222220000000000000000000 112111211110000000000000112111111111121111211111211111
M43-1   11111222211111111111122222222222122211221111122111122221122211121111112211111111111 11211121111111122221111112111111111111211121111121111
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F36-1   2211111111111111111121111111110000000000000000000000000222222000000000000000000000000112111121111000000000000011211111111121112111112111111
F35-1   11111222221111111111222222222112222112211111111111222222122111111111112111111111111111112111211111111112221111121112221111112111211111211111
F34-1   122221111111111111112222222221122221121111112111111222221122222112222111222222111111111111111211121111122222111111111121111111111211121111121111111
F30-1   11122222111111111111222222221122211211111211111222221122222111111111112222111111111122111111111111111111211121111111122211111121111111111001112111112111111
F29-1   22111111111111111111211111111100000000000000000000000002222220000000000000000000000001121111211110000000000000112111111111112111111112111111112
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                                                                                                  X-BED   FOSS    COLOUR
SAMPLE UNIT   METER  GRAIN SIZE        ROUNDNESS  SOR     %        %       LWRC   RIP        MC       B FRES WEAT
NAME   THICK  ABOVE                     V   S S   W      DARK    CARB      CNTHLAM          TTUO     AI LDGDR GR
       METER  BASE   1 2 3 4 5 6 7 8 A A A R R RPMW   MINERAL MATR      ESGA    ASCSLPARDN ARPBO GGGYGGGGB
|    | |   | |    | |              ||           || | |          ||      | | ||| || ||     ||| |  || |   ||  |
  S1-1  1.10   0.60 1111111111111221111122211111210 222222122221110 11111111101111111 12111 211111112
  S2-1  0.10   1.20 1111112222111111111222111111120 222222112222110 21111111101111111 21111 211112111
  S3-1  1.70   2.50 1111111111111221111121222112110 222222212222110 21111111101111111 21111 211112111
  S4-1  0.90   3.40 1111111111111221111121222111120 222222212222210 12111111101111111 21111 211112111
  S5-1  0.80   4.40 1111111121212221111122221111210 222222212222210 21111111101111111 21111 211111112
  S6-1  0.85   5.30 1111112222111111112122211111120 222222112222110 11111211101111111 21111 121112111
  S7-1  0.30   6.10 1122221111111111111222111111210 222221112222110 21111111101111111 21111 121112111
  S8-1  0.50   6.10 2221111111111110000000000000000 000000000000000 12111111101111111 12221 121112111
  S9-1  1.00   7.10 2222111111111110000000000001210 000000021111110 12111111101111111 21111 121112111
 S10-1  0.70   7.10 2122221111111110000000000002110 000000012221110 21111111101111121 21111 121112111
 S11-1  0.90   8.50 2222111111111111111222111111210 222211112222110 21111111101111111 21111 211112111
 S12-1  2.40  11.00 2211111111111110000000000001210 000000021111110 21111111101111111 21112 211112111
 S13-1  1.00  12.00 1112211111111111112221211111120 221111121111110 21111111101111111 21111 211111112
 S14-1  0.48  12.70 1111111111111221112222111111120 222222112222110 21111111101111111 21111 211111112
 S15-1  1.40  14.00 1221111111111110000000000001210 221111121111110 21111111101111111 21111 211112111
 S16-1  2.70  16.40 2221111111111110000000000001120 000000021111110 21111111101111111 21111 211112111
 S17-1  2.00  16.80 1111222111111111111122211111120 222221112222110 21111111102112111 12211 211112111
 S17-2  1.40  18.80 1111222111111111111122211111120 222111112111110 12111111101111111 21111 211112111
 S18-1  1.70  21.50 2211111111111110000000000001210 000000021111110 21111111101111121 12211 211112111
 S19-1  1.00  22.60 1112211111111111112221111111120 211111112111110 21111111101111111 21111 211112111
 S20-1  0.10  23.00 1122211111111111111222111111120 221111121111110 21111111102112111 21111 211112111
 S21-1  1.00  23.90 2222111111111111111122211111210 000000021111110 21111111101111111 21112 211112111
 S22-1  0.20  24.00 1122221111111111112222111112110 221111121111110 21111111101111111 21111 211112111
 S23-1  0.55  24.70 1221111111111110000000000001210 222111112211110 21111111102112111 21111 211112111
 S24-1  2.00  24.50 2211111111111110000000000001210 000000021111110 21111111101111111 21111 121112111
 S25-1  1.20  26.10 1221111111111110000000000001210 222111112111110 21111111101111111 21112 211112111
 S26-1  1.00  27.20 2222111111111110000000000002110 211111121111110 21111111101111111 21112 211112111
 S26-2  2.70  28.20 1221111111111110000000000002110 111111121111110 12111111101111111 21111 211112111
 S27-1  0.70  30.40 2222111111111110000000000002110 111111121111110 21111111101111111 21111 211112111
 S28-1  1.30  31.50 2222111111111110000000000002110 000000012111110 21111111101111111 21111 211112111
 S29-1  0.30  32.10 2211111111111110000000000001210 000000012211110 21111111101111111 21111 121110211
 S30-1  1.50  33.40 1221111111111110000000000001210 221111121111110 21111121101111111 21111 211112111
 S31-1  0.60  34.10 2122211111111111122221111112110 222211112211110 12111111101111111 21111 121112111
 S32-1  0.60  34.60 2211111111111110000000000001120 111111121111110 21111111101111111 21111 211112111
 S33-1  0.25  35.10 2222111111111110000000000002110 211111121111110 21111111101111111 21111 211112111
 S34-1  0.40  35.40 2211111111111110000000000002110 222111112221110 21121111101111111 21112 211112111
 S35-1  0.45  35.80 1221111111111110000000000001210 111111121111110 21111111101111111 21111 211112111
 S36-1  0.25  36.10 2221111111111111122111111111210 222211112111110 21111111101111111 21111 211112111
 S37-1  0.50  36.40 2221111111111110000000000001210 000000000000000 21111111101111111 21112 211112111
 S38-1  0.25  36.90 2122211111111111222221111112110 222111121111110 21111111101111111 21111 211112111
 S39-1  0.30  37.10 2122211111111111112221111111110 222211112211110 21111111101111111 21111 211112111
 S40-1  0.40  37.50 2211111111111110000000000002110 000000000000000 21111111101111121 21111 211112111
 S41-1  0.40  38.00 1121222111111111122221111112110 222221121111110 21111111101111121 12211 211112111
 S42-1  1.75  39.50 2111111111111110000000000001120 111111121111110 21111111101111111 21112 211112111
 S43-1  0.60  40.20 2221111111111110000000000001210 000000000000000 21111111101111111 21111 211112111
 S44-1  0.10  40.50 2111111111111110000000000001120 000000000000000 21111111101111111 12211 211112111
 S45-1  0.40  40.80 1121222111111111122211111112110 222221112222110 21111111101111111 12211 211112111
 S46-1  0.20  41.10 1111212221111111222211111112110 222222112221110 12111111101111111 21111 211112111
 S47-1  0.70  41.50 2111111111111110000000000001120 000000021111110 21111111101111111 21111 211112111
 S48-1  0.40  42.10 2221111111111110000000000002110 000000000000000 21111111101111111 21111 211112111
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                                                                                      X-BED   FOSS    COLOUR
SAMPLE UNIT   METER  GRAIN SIZE        ROUNDNESS  SOR       %       %    LWRC   RIP      MC      B FRES WEAT
NAME   THICK. ABOVE                    V   S S    W       DARK    CARB   CNTHLAM         TTUO   AI LDGDR GR
       METER  BASE   1 2 3 4 5 6 7 8 A A A R R RPMW    MINERAL MATR   ESGA   ASCSLPARDX ABPBD GGGYGGGGB
|    | |   | |    | |               ||          || | |       ||     | | ||| || ||    ||| |  || |   || |
 S49-1  0.40  42.50 211111111111111100000000000001210 000000000000000 21111111101111111 12211 211112111
 S50-1  0.30  42.80 222211111111111112222211111112110 111111121111110 21111111101111111 21111 211112111
 S51-1  0.33  43.20 211111111111111100000000000000000 000000000000000 21111111101111111 21111 121112111
 S52-1  0.40  43.50 222111111111111112222111111112110 000000000000000 21111111101111111 21112 211112111
 S53-1  0.15  43.80 211111111111111100000000000001120 000000000000000 21111111101111111 12211 121112111
 S54-1  1.50  45.10 112221111111111112222111111111210 222221112222110 21111111102100011 21111 211112111
 S55-1  0.50  45.50 222111111111111111122221111112110 222211121111110 21111111101111111 21111 211112111
 S56-1  0.30  46.10 212122211111111111222121111112110 222211112111110 11111111101111121 21111 211112111
 S57-1  0.50  46.50 122111111111111100000000000001120 211111121111110 21111111101111111 21111 211112111
 S58-1  0.30  46.80 112222111111111112222111111112110 222211112211110 21121111101111111 21111 211111112
 S60-1  0.50  47.60 222211111111111112222111111111210 222211121111110 21111121101111111 21111 211111112
 S61-1  0.25  48.00 211111111111111100000000000001120 000000000000000 21111111101111111 12211 121112111
 S62-1  0.22  48.20 112221111111111112222111111111210 222211112221110 21121121101111111 21111 211112111
 S63-1  0.78  49.00 111121222111111112222121111111210 222222112222110 21121121101111111 21111 211112111
 S64-1  1.10  50.10 212221111111111112222111111111210 222111121111110 21121121101111111 21111 211112111
 S65-1  1.20  51.20 112121222111111111122221111112110 222211112111110 21111111101111111 21111 211112111
 S67-1  2.50  55.90 111221111111111111122221211111120 222211112111110 21111111101111111 21111 211112111
 S71-1  0.85  60.10 111122211111111111122221111111210 222221112222210 21111111101211211 21111 211112111
 S72-1  0.20  60.60 211111111111111100000000000001120 000000000000000 21121111101111111 21111 121112111
 S73-1  0.60  61.10 222111111111111100000000000001210 000000012211110 21111111102111211 21111 211112111
 S74-1  1.70  62.50 111121222111111111112221111112110 222221112211110 21111111102111211 21111 211112111
 S75-1  0.30  63.10 221111111111111100000000000001210 000000000000000 21111111101111112 21111 121112111
 S76-1  0.50  63.50 122211111111111111122211111111210 222111112111111 21111111101111111 21111 211111112
 S77-1  0.25  64.00 221111111111111100000000000001210 000000012111110 21111111101111111 21111 121112111
 S78-1  1.70  65.50 222111111111111100000000000002110 211111121111110 21111111101111111 21111 211112111
 S79-1  1.40  66.90 111112221111111111122212111111210 222211112111110 21111111101211211 21111 211112111
 S80-1  1.10  68.20 222111111111111100000000000001210 221111112111110 12111111101111111 21111 211112111
 S81-1  0.28  68.40 221111111111111100000000000002110 211111121111110 21111111101111111 21111 211112111
 S83-1  1.60  71.40 221111111111111100000000000002110 000000000000000 21111111101111111 21111 121112111
 S84-1  1.00  72.30 111111222111111111122212111111210 222221112221110 21111111101111111 21111 211112111
 S85-1  2.15  74.20 222211111111111100000000000002110 222111112111110 21111111101111111 21111 211112111
 S87-1  0.60  75.50 211111111111111100000000000001210 211111121111110 21111111101111111 21111 211112111
 S89-1  0.45  76.50 221111111111111100000000000001210 000000000000000 21111111101111111 12111 121112111
 S90-1  0.70  77.20 112221111111111112222111111111110 222221112211110 21111111101111111 21111 211112111
 S91-1  1.40  78.50 221111111111111100000000000001210 111111121111110 12111111101111111 21111 211112111
 S92-1  0.80  79.40 122111111111111100000000000001120 211111121111110 21111111101111111 21111 211112111
 S93-1  2.00  81.60 222111111111111100000000000002110 000000000000000 21111111101111111 21111 211112111
 S94-1  0.25  81.80 122111111111111100000000000001120 211111112111110 21111111101111111 21111 211111112
 S96-1  0.90  86.50 211111111111111100000000000001120 211111121111110 21111111101111111 21111 211112111
 S97-1  0.35  87.10 221111111111111100000000000002110 000000000000000 21111111101111111 21111 121112111
 S98-1  0.80  87.80 212221111111111112222111111111210 222211112211110 21111111101111111 21111 211112111
 S99-1  0.65  89.40 122111111111111111122221111111210 222111112111110 21111111101111111 21111 211112111
S100-1  0.70  90.10 211111111111111100000000000001120 000000000000000 21111111101111111 12211 121112111
S101-1  1.70  91.50 122111111111111111111222111111120 221111121111110 21111111101111111 21111 211112111
S102-1  2.00  93.40 211111111111111100000000000001120 000000000000000 21111111101111111 21111 211112111
S103-1  1.80  95.40 222111111111111100000000000002110 211111121111110 21111111101111111 21111 211112111
S104-1  0.20  95.80 212221111111111100000000000002110 222211112221110 21111111102111211 21111 211112111
S106-1  0.68  96.30 222211111111111100000000000002110 211111121111110 21121111101111111 21112 121112111
S107-1  0.90  97.60 122111111111111112222111111111120 222111112111110 21111111101111112 21111 211112111
S108-1  0.25  97.90 212221111111111112222111111112110 222211112211110 21111111101111111 21111 211112111
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                                                                                    X-BED    FOSS    COLOUR
SAMPLE  UNIT   METER  GRAIN SIZE        ROUNDNESS  SOR     %       %     LWBC   RIP      MC      B  FRES WEAT
NAME    THICK  ABOVE                    V   S S    W      DARK    CARB   CNTHLAM        TTUO    AI  LDGDR GR
        METER  BASE   1 2 3 4 5 6 7 8 A A A R R  RPSW  MINERAL  MATR   ESGA   ASCSLPARDN  ARPBO  GGGYGSGGB
|     | |   | |    | |              ||          || |  |       ||      | | ||| || ||    |||  |  ||  |  ||  |
S109-1  0.40   98.20  2111111111111110000000000001120  000000000000000  12111111101111111  21111  112112111
S110-1  0.70  100.50  2122211111111111111222111111210  222111121111110  21111111101111111  21111  211112111
S111-1  0.70  101.10  2222111111111110000000000001210  211111121111110  21111111101111111  21111  211112111
S112-1  0.30  101.20  2111111111111110000000000001120  000000000000000  12111111101111111  21111  112112111
S113-1  0.70  102.10  2211111111111110000000000001120  000000000000000  12111111101111111  21111  211112111
S114-1  0.40  102.40  2221111111111111222212111111120  211111121111110  21111111101111111  21111  211112111
S116-1  1.15  106.80  2211111111111110000000000001210  000000000000000  00111111101111111  21111  112112111
S117-1  0.85  107.50  2211111111111110000000000002110  211111121111110  12111111101111111  21112  111212111
S119-1  0.70  108.80  2111111111111110000000000001120  111111121111110  21111111101111111  21111  111212111
S120-1  1.10  109.50  2211111111111110000000000002110  000000000000000  21111111101111111  21111  211112111
S121-1  0.30  110.10  2211111111111110000000000002110  211111121111110  12111111101111111  21111  211112111
S122-1  0.20  111.30  2222111111111111222211111112110  221111112111110  00111111101111111  21111  112112111
S123-1  0.20  112.50  2221111111111110000000000002110  222111112111110  00111111101111111  21111  211112111
S124-1  0.60  114.30  2122211111111111111122211112110  211111121111110  21111111101111111  21111  211112111
S125-1  0.80  118.20  2211111111111110000000000001120  211111121111110  21111111101111112  21111  211112111
S126-1  0.80  119.10  1111222111111111111222211111210  222221112221110  21111111101111111  21111  211112111
S128-1  0.15  119.40  1111212221111111111122221111210  222221112222110  21111111101111111  21111  211112111
S129-1  0.45  119.90  2111111111111110000000000001120  000000021111110  21111111101111111  21111  121112111
S130-1  0.35  120.10  2211111111111110000000000001210  211111121111110  21111111101111111  21111  211112111
S131-1  0.55  120.50  2111111111111110000000000001120  111111121111110  21111111101111111  21111  211112111
S132-1  0.45  121.10  2221111111111110000000000002110  222211121111110  21111111101111111  21111  211112111
S133-1  0.35  121.50  2211111111111110000000000002110  000000000000000  12111111101111111  21111  111212111
S134-1  0.20  123.10  1121222111111111111222211112110  222221112222110  21111111101111111  21111  211112111
S135-1  1.40  123.50  2211111111111110000000000002110  000000000000000  21111111101111111  21111  111212111
S137-1  0.60  130.50  2221111111111110000000000001210  222111112211110  21111111101111111  21111  211112111
S138-1  0.30  130.80  2211111111111110000000000001120  000000000000000  21111111101111111  21111  111212111
S139-1  0.40  131.20  2122211111111111111122211112110  222211112211110  21111111101111111  21111  211112111
S140-1  0.35  132.10  2221111111111110000000000001210  222111112211110  00111111101111111  21111  112112111
S141-1  0.30  133.50  2222111111111111111222211112110  222111112111110  21111111101111111  21111  112112111
S142-1  0.40  134.50  2222121111111111122221111112110  222111112111110  21111111101111111  21111  112112111
S143-1  1.60  136.50  2122211111111110000000000000000  222211112211110  21111111101111111  21111  211112111
S163-1  1.40  170.50  1111222111111111122221211112110  222221121111110  21111111101111111  21111  111212111
S164-1  0.55  171.40  2111111111111110000000000001120  000000021111110  21111111101111111  21111  111212111
S165-1  0.25  171.50  1121212221111111122221111112110  222221112221110  21111111101111111  21111  111212111
S166-1  0.80  172.40  2111111111111110000000000001120  000000021111110  21111111101111111  21111  121112111
S167-1  1.70  173.90  1111122211111111222211111111210  222222112222110  21111111102111221  21111  111212111
S168-1  0.30  174.40  2211111111111110000000000001210  000000021111110  12111111101111111  21111  111212111
S169-1  0.80  175.20  2122211111111111222121111112110  222222112222110  12111111101111111  21111  111212111
S170-1  2.00  177.40  2221111111111111222211111112110  222221112221110  00111211102100011  21111  111212111
S170-2  0.30  179.30  2211111111111110000000000002110  222221121111110  12111111101111111  21111  111212111
S171-1  0.25  179.90  2111111111111110000000000001120  000000021111110  21111111101111111  21111  121112111
S172-1  0.60  180.40  2222111111111111222211111112110  222222112222210  21111111102100011  21111  111212111
S173-1  0.25  180.60  2111111111111110000000000001120  000000012222110  12111111101111111  12211  121112111
S174-1  0.33  181.10  2222111111111111222111111112110  222222112222210  21111111101111111  21111  111212111
S176-1  0.25  181.50  1122221111111111222211111112110  222222112222210  21111111101111111  21111  111212111
S177-1  0.35  181.90  1111122211111111112222111111210  222222112211110  21111111101111111  21111  111212111
S178-1  0.85  182.70  1111222211111111111222211111210  222221121111110  12111111101111111  21111  111212111
S179-1  2.00  184.50  1111222111111111111122221112110  222221112222110  12111111101111111  21111  111212111
S180-1  2.00  186.50  2211111111111110000000000002110  000000012221110  21111111101111111  21112  111212111
S181-1  2.00  186.90  1111122211111111112222111112110  222221112222110  21111111101111111  21111  111212111
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                                                                                      X-BED   FOSS    COLOUR
SAMPLE UNIT   METER  GRAIN SIZE       ROUNDNESS  SOR      %        %      LWBC   RIP       MC        B FRES WEAT
NAME   THICK  ABOVE                   V   S S    W      DARK     CARB     CNTHLAM          TTUO     AI LDGDR GR
       METER  BASE    1 2 3 4 5 6 7 8 A A A R R RPMW   MINERAL  MATR      ESGA   ASCSLPARDN       ARPBO GGGYGSGGB
|    | |   | |    | |              ||          || | |         ||    |    | ||| || ||     |||       |  ||  |   ||  |
S181-2  2.00 188.90 1111112221111111222211111111210 222222112222110 12111111101111111 21111 111212111
S181-3  2.00 190.90 1111222111111111122211111112110 222222112222110 12111111101111111 21111 111212111
S181-4  2.00 192.90 1111222111111111122211111112110 222222112222210 12111111101111111 21111 111212111
S181-5  2.00 194.90 1112221111111111122211111112110 222222112222110 12121111101111111 21111 111212111
S181-6  2.00 196.90 1111212221111111112221111112110 222222112222110 12111111101111111 21111 111212111
S181-7  1.60 198.90 1111112221111111222211111111210 222221112111110 12111111101111111 21111 111212111
S182-1  0.45 200.80 2221111111111110000000000002110 000000012222110 12121111101111111 21111 111212111
S183-1  0.38 201.20 2211111111111110000000000002110 000000012222110 12121111101111111 21112 111212111
S184-1  0.40 201.50 1122211111111111112221111111210 222222112222110 21111111101111121 21111 111212111
S185-1  0.50 202.10 2211111111111110000000000002110 000000000000000 12111111101111111 21111 111212111
S186-1  0.80 202.70 2221111111111111222111111112110 222222112222210 21111111101111111 21111 111212111
S187-1  0.30 203.10 2111111111111110000000000001120 000000021111110 21111111101111111 12112 121112111
S188-1  1.10 203.90 2211111111111110000000000002110 000000012222110 21111111101111111 12211 111212111
S189-1  1.60 205.10 1122221111111111112221111112110 222221112222110 21121111101111121 21111 111212111
S190-1  1.30 207.10 2111111111111110000000000001120 000000021111110 21112111101111111 12111 121112111
S192-1  0.35 207.80 1122211111111111112222111112110 222222112222210 21111111101111111 12211 111212111
S193-1  0.31 208.10 2222111111111111222111111112110 000000012222210 12111111101111111 12211 111212111
S194-1  0.75 208.90 2211111111111110000000000001210 000000012222210 12121111101111111 12111 121112111
S195-1  1.40 210.30 1111222111111111222211111112110 222222112222110 21111111101111111 21111 111211211
S196-1  1.60 212.50 2111111111111110000000000001120 000000000000000 00111111101111111 21112 111211211
S197-1  2.00 213.10 1111222211111111112221111111210 222221112211110 21111111101111111 21111 111211211
S197-2  2.00 214.90 1111222111111111222121111112110 222222112222210 12111111101111111 21111 111211211
S197-3  2.00 216.90 1111222111111111222111111112110 222221112222110 12111111101111111 21111 111211211
S198-1  0.95 221.30 2222111111111111222111111112110 222222112222210 21121111101111111 21111 121111211
S199-1  0.30 221.60 2211111111111110000000000002110 000000012222210 21111111101111111 12112 121112111
S201-1  0.90 222.90 2222111111111111222111111112110 222221112221110 21111111101111111 21111 111212111
S202-1  0.30 223.20 2221111111111111122211111112110 222211112221110 12111111101111111 21111 111212111
S203-1  0.60 223.80 2222111111111111122211111112110 222211112211110 12111111101111111 21111 111211211
S204-1  1.85 225.20 2111111111111110000000000001120 000000021111110 21111111101111111 21112 121111211
S205-1  0.60 226.10 2221111111111111222211111112110 222221112222110 21111111101111111 21111 111211211
S206-1  2.40 228.10 2211111111111110000000000002110 222221112222110 00111111101111111 21112 111211211
S207-1  0.55 229.10 2221111111111111222211111112110 222221112221110 21111111101111111 21111 111212111
S208-1  0.30 229.50 2111111111111110000000000001210 000000000000000 21[illegible]11111101111111 12212 121112111
S209-1  0.53 230.10 1122211111111111222211111112110 222222112222110 21111111101111121 21111 111212111
S210-1  0.30 230.30 2211111111111110000000000001210 000000021111110 12111111101111111 21111 121112111
S211-1  0.20 230.50 1122221111111110122111111112110 222222112222110 21111211102111211 21111 111211211
S212-1  0.60 231.20 1122211111111111222211111112110 222222112222210 12111111101111111 21112 111211211
S213-1  0.53 231.50 2221111111111111122211111111110 222222112222210 12111111101111111 12211 111211211
S214-1  0.65 232.20 2122211111111111122211111112110 222221112222110 21111111101111111 21111 111211211
S215-1  3.90 234.50 2221111111111110000000000001120 222211112222110 21111111101111111 21111 111211211
S216-1  2.40 236.90 1122211111111111222111111111210 222221112222210 21111111101111121 12211 111211211
S217-1  0.90 238.50 1112222111111111122211111112110 222211112221110 21111111101111111 21111 111212111
S218-1  0.90 239.50 2211111111111110000000000001210 222222112222220 21111111101111111 21112 111212111
S219-1  0.40 240.10 2221111111111110000000000002110 222222112222210 21112111102112111 21111 111212111
S220-1  1.40 241.20 2111111111111110000000000001120 000000000000000 21121111101111111 21111 121112111
S221-1  0.50 241.90 1221111111111111222211111111120 222222112222210 12121111102111211 21111 111212111
S222-1  1.50 242.90 2211111111111110000000000002110 222222112222210 21121112101111111 21111 121112111
S223-1  0.50 243.90 2221111111111110000000000002110 222222112221110 21111111101111111 21111 111212111
S224-1  0.50 244.10 1121222111111111122211111112110 222211121111110 21111111101111121 21111 111211211
S225-1  0,75 245.10 2211111111111110000000000002110 222211112211110 12112111101111111 21111 111212111
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                                                                                  X-BED   FOSS    COLOUR
SAMPLE UNIT   METER  GRAIN SIZE        ROUNDNESS   SOR     %        %      LWRC   RIP       MC       B FRES WEAT
NAME   THICK  ABOVE                    V   S S     W      DARK     CARD    CNTHLAM         TTUO     AI LDGDR GR
       METER  BASE    1 2 3 4 5 6 7 8  A A A R R   RPMW   MINERAL  MATR    ESGA   ASCSLPARDN  ARPBO GGGYGGGGB
|    | |   |  |   |  |             ||              || |   |        ||    | | ||| || ||     |||  |  || |   || |
S227-1  1.20 246.90 1122211111111112221111111112110 222221112222110 12121111101111121 21111 111212111
S228-1  0.40 247.80 2211111111111110000000000001210 000000000000000 12112112101111111 21111 111212111
S229-1  1.65 249.10 2221111111111110000000000002110 222221112222110 21121111101111111 21111 111212111
S230-1  2.55 251.80 2211111111111110000000000002110 222211121111110 12111111101111111 21111 111212111
S232-1  0.45 253.70 2221111111111111122211111111210 222221112221110 21111111101111111 21111 111211211
S233-1  0.50 254.10 2211111111111110000000000021100 000000000000001 11111111101111111 21111 111212111
S234-1  2.00 245.40 1111222111111111122211111111210 222221112222110 21111111101111121 21111 111212111
S234-2  1.40 256.40 1122211111111111222111111111210 222221112221110 12111111101111112 21111 111212111
S235-1  1.30 258.70 2111111111111110000000000001120 000000000000000 12111111101111112 21111 111212111
S236-1  0.30 259.20 1111222211111111122211111111210 222221112221110 21111111101111121 21111 111211211
S237-1  2.30 260.50 2211111111111110000000000001210 000000000000000 12111111101111111 21112 111212111
S239-1  0.45 264.10 2221111111111110000000000002110 222221112222110 21111111101111111 21111 111211211
S240-1  0.25 264.30 1121222111111111122211111112110 222211112221110 12111111101111111 21111 111211211
S241-1  2.00 264.50 2221111111111111122211111112110 222211112221110 12112111101111121 21111 111212111
S241-2  2.00 266.40 2111111111111110000000000001120 000000000000000 21111111101111111 12211 111211211
S243-1  1.60 270.90 2221111111111111222211111112110 222221112222210 21111111102112111 12211 111212111
S244-1  1.85 272.60 1112221111111111122211111112110 222221112222110 21111111101111111 21111 111211211
S245-1  2.10 273.10 2211111111111110000000000001210 000000000000000 21121111102112111 21111 111212111
S245-2  1.50 275.10 2211111111111110000000000002110 000000000000000 12111111101111111 21111 111212111
S246-1  0.20 276.70 2211111111111110000000000002110 000000012222110 21111112101111111 21112 111212111
S248-1  2.10 278.90 2111111111111110000000000001210 000000012111110 12111111101111111 21112 111212111
S250-1  0.25 280.10 2221111111111110000000000002110 000000000000000 12111111101111111 21111 111212111
S251-1  0.60 280.70 2211111111111110000000000001210 221111112211110 12111111101111111 21111 111212111
S252-1  0.22 281.00 2221111111111110000000000002110 222111112111110 12111111101111121 21111 111212111
S253-1  0.28 281.30 2221111111111111122211111112110 222111112111110 12111111101111111 21111 111212111
S254-1  1.12 282.10 2221111111111111122211111112110 222111112111110 21121111101111111 21111 111212111
S255-1  1.35 283.10 1122211111111111122211111112110 222211112211110 21111111101111111 21111 111211211
S256-1  1.05 284.10 2221111111111110000000000002110 222211112221110 12111111101111111 21111 111212111
S257-1  0.45 285.10 2211111111111110000000000001210 000000000000000 00121121101111111 21111 111212111
S258-1  0.85 286.10 1221111111111111122111111111210 221111112111110 00111111101111111 21111 111212111
S259-1  0.70 286.60 2211111111111110000000000001210 000000012221110 21111111101111111 12211 111211211
S260-1  0.20 286.80 1111111122211111112222111112110 222211112111110 21111111101111111 21111 111212111
S260-2  1.80 287.10 1111111122211111112222111112110 222211112111110 12111111101111111 21111 111212111
S260-3  2.00 288.80 1111112221111111112221111111210 222221112222110 12111111101111111 21111 111212111
S260-4  2.00 290.80 1111112221111111112221111112110 222221112222210 12011111101111111 21111 111212111
S260-5  2.00 292.80 1111122211111111112222111112110 222221112221110 12111111101111111 21111 111212111
S260-6  2.00 294.80 1111112221111111112222111112110 222211112111110 12111111101111111 21111 111212111
S260-7  2.00 296.80 1111112221111111112221111112110 222211112111110 12111111101111111 21111 111212111
S260-8  1.00 298.80 1111112221111111112221111112110 222211112221110 12111111101111111 21111 111212111
S260-9  1.00 299.80 1111112221111111122211111111210 221111121111110 12111111101111111 21111 111212111
S260-0  0.50 300.80 1111112221111111122211111112110 222111112111110 12111111101111111 21111 111212111
S261-1  0.50 301.50 2221111111111111222111111112110 222221112222110 21111111101111111 21111 121112111
S262-1  0.15 302.10 2211111111111110000000000001210 000000021111110 12111111101111111 21111 121112111
S264-1  2.00 302.80 1122211111111111222111111112110 222221112222110 2[illegible]1111101111111 21111 111211211
S264-2  1.10 304.20 2222111111111111222111111112110 222221112222210 21121111101111111 21111 111211211
S265-1  0.30 305.60 2221111111111110000000000002110 222211112221110 12111111101111111 21111 121112111
S266-1  0.35 306.00 2211111111111110000000000002110 000000000000000 21111111101111111 21111 111212111
S267-1  1.90 307.10 2111111111111110000000000001210 000000000000000 12111111101111111 21111 121112111
S268-1  0.80 308.50 2111111111111110000000000001120 000000000000000 12111111101111111 21111 111212111
S269-1  2.25 310.50 2222111111111111222211111111210 222211112111110 21111111101111111 21111 111212111
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SAMPLE UNIT   METER  GRAIN SIZE        ROUNDNESS   SOR     %       %     LWRC    RIP        X-BED   FOSS    COLOUR
NAME   THICK  ABOVE                    V   S S   W        DARK    CARB   CWTHLAM        MC          B   PRES WEAT
       METER  BASE    1 2 3 4 5 6 7 8 A A A R R  RPMW    MINERAL  MATR   ESGA         TTUO        AI  LDGDR GR
                                                                                     ASCSLPARDN  ANPBD GGGYGGGGD
|     | |   | |    | |              ||           || |  |           ||    |  | |||  || ||      ||| |   || |   || |
S270-1  0.80 311.40 2111111111111110000000000001210 221111112111110 21111111101111111 21111 111212111
S271-1  2.20 314.80 2221111111111111222211111112110 221111112111110 21111111101111111 21111 111212111
S272-1  0.40 316.10 2211111111111110000000000002110 222111112111110 12121111101111111 21111 111212111
S273-1  0.65 316.50 2221111111111110000000000002110 222111112111110 21111111101111111 21111 111212111
S274-1  1.60 318.10 2111111111111110000000000001210 222111112111110 21111111101111111 21111 111212111
S275-1  6.20 324.80 2111111111111110000000000001120 000000000000000 00121111101111111 12211 121112111
S276-1  0.55 327.20 1122211111111111222211111112110 222211112221110 21111111101111111 21111 111212111
S277-1  0.35 327.60 2111111111111110000000000001120 000000000000000 12111111101111111 21111 111212111
S278-1  0.18 327.80 2211111111111110000000000001210 000000000000000 21111111101111111 21111 111212111
S279-1  0.85 328.60 4111222111111111122211111112110 222221121111110 21111111101111111 21111 111212111
S280-1  0.37 331.10 2111111111111110000000000001120 000000012222110 21111121101111111 12211 111212111
S282-1  2.00 336.10 2221111111111110000000000001210 222211112221110 21111111101111111 21111 111212111
S284-1  2.00 338.60 2222111111111111122211111112110 221111121111110 21111111101111111 21111 111212111
S285-1  2.00 339.60 1122211111111111222211111111210 222211121111110 21111111101111111 21111 111211211
S285-2  1.60 341.60 1122211111111111122211111112110 222211112211110 12111111101111111 21111 111211211
S286-1  2.00 343.20 2221111111111110000000000002110 222111112111110 12111111101111111 21111 111211211
S286-2  1.30 345.20 2222111111111110000000000002110 222111112111110 12111111101111111 21112 111211211
S287-1  2.00 346.50 1111112222111111122211111112110 222221112221110 21111111101111121 12211 111212111
S287-2  1.45 348.50 1111112221111111122211111112110 222221112222110 12111111101111121 12211 111212111
S289-1  3.00 353.70 2111111111111110000000000001210 000000021111110 12111121101111111 21111 121112111
S290-1  2.00 354.70 2221111111111111122211111112110 222221112222110 21111121101111111 21111 111211211
S290-2  2.00 356.70 1122211111111111122211111112110 222221112221110 12111111101111111 21111 111211211
S290-3  0.70 358.70 1122211111111111122211111112110 222221112221110 12111111101111111 21111 111211211
S291-1  3.55 361.80 2111111111111110000000000001120 000000000000000 21111111101111111 21112 111211211
S293-1  0.45 363.90 2221111111111110000000000002110 222221112222110 21121111101111111 21111 111212111
S295-1  0.80 365.20 2221111111111111122211111111210 222211112221110 121111111[illegible]1111111 21112 111211211
S296-1  1.00 365.90 2111111111111110000000000001120 111111121111110 211111111[illegible]1111111 21112 111211211
S297-1  1.10 366.90 2122211111111111111222111112110 221111121111110 21111111101111111 21111 112111211
S298-1  0.12 367.50 2111111111111110000000000001210 000000000000000 21111111101111111 21112 111211211
S300-1  1.70 370.80 1122211111111111222211111112110 222221112222110 21111111101111111 21111 111211211
S301-1  0.90 372.90 2222111111111111222211111112110 222221112222110 00111111101111121 21112 111211211
S302-1  2.90 374.50 2211111111111110000000000001210 000000021111110 21111111101111112 21111 111211211
S303-1  0.65 376.40 2211111111111110000000000002110 000000021111110 21111111101111121 21111 111211211
S304-1  1.80 377.90 2111111111111110000000000001120 000000000000000 21111111101111111 21111 111212111
S305-1  2.00 379.50 1122211111111111222211111112110 222211112211110 21111111101111111 21111 111211211
S307-1  0.88 381.50 2111111111111110000000000001120 000000000000000 12111111101111111 21111 111211211
S308-1  1.40 382.90 2221111111111111222211111112110 222221112221110 21121111101111111 21111 111211211
S309-1  0.80 383.60 2211111111111110000000000001210 000000000000000 21111111101111111 21112 111211211
S310-1  0.60 388.90 2221111111111111222211111112110 222211112211110 21111111101111111 21111 111211211
S311-1  1.25 389.90 2111111111111110000000000001120 000000000000000 21111111101111111 12112 111211211
S312-1  0.45 390.40 1122211111111111122211111112110 222221112221110 21111111102111211 21111 111212111
S313-1  0.25 390.90 2221111111111110000000000002110 222211112221110 21111111101111111 21111 111211211
S314-1  3.70 392.70 2211111111111110000000000001210 222221100000000 21111111101111111 21112 111212111
S315-1  0.35 394.90 2222111111111111222211111112110 222111112111110 21111111101111111 21111 111211211
S319-1  1.00 413.90 1122221111111112221111111112110 222211112221110 00111111101111111 21111 121112111
S320-1  0.60 414.90 2222111111111110000000000002110 222111100000000 21111111101111111 21111 121112111
S321-1  0.50 415.30 1122211111111111122211111112110 222221112221110 21111111101111111 21111 111212111
S322-1  0.55 415.90 2222111111111110000000000002110 222221112222110 21111111101111111 21111 111212111
S323-1  2.00 417.10 2222111111111110000000000002110 222211112211110 21111111101111111 12211 111212111
S324-1  1.00 418.10 2211111111111110000000000002110 222221112222210 21121111101111111 21112 111212111
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                                                                              X-BED   FOSS    COLOUR
SAMPLE UNIT  METER   GRAIN SIZE      ROUNDNESS  SOR    %       %    LWRC   BIP     MC     B FRES WEAT
NAME   THICK ABOVE                   V   S S   W     DARK   CARB    CNTHLAM      TTUO    AI LDGDR GR
       METER BASE    1 2 3 4 5 6 7 8 A A A R R RPMW MINERAL MATR    ESGA   ASCSLPARDN ARPBO GGGYGGGGB
|    | |   | |    | |              ||          || | |      ||     | | |||  || ||  ||| |  || |    || |
S325-1  1.50 420.50 2222111111111110000000000002110 222211112221110 21111111101111111 21111 121111211
S326-1  1.80 421.30 2211111111111110000000000001210 222111112111110 21111111101111111 12221 121112111
S327-1  0.35 422.50 1122221111111111222211111111210 222211112111110 21111111101111111 21111 111212111
S328-1  0.25 422.80 2211111111111110000000000001210 221111112111110 21111111101111111 21111 211112111
S329-1  0.10 423.00 2222111111111111112222111112110 222211112211110 21111111101111111 21111 211112111
S330-1  0.10 423.10 2211111111111110000000000001210 000000000000000 21111111101111111 21111 211112111
S331-1  0.35 423.40 1122221111111111222211111111210 222211112211110 21111111101111111 21111 211112111
S332-1  0.88 424.10 2111111111111110000000000001120 000000000000000 21111111101111111 21111 111211211
S333-1  1.10 424.90 1122211111111111222211111111120 211111112111110 21111111101111121 21111 111211211
S335-1  2.70 435.10 2221111111111110000000000002110 222211112221110 21111111101111121 21111 121112111
S336-1  1.45 436.90 2111111111111110000000000001120 111111112111110 21111111101111111 21111 111121121
S337-1  0.45 437.50 2222111111111111112222111111210 222111112111110 21111111101111111 21111 111121121
S338-1  1.25 437.90 2211111111111110000000000002110 222211112211110 21111111101111111 21110 111121121
S340-1  0.25 439.50 2222111111111110000000000002110 000000000000000 21111111101111111 21112 111121121
S341-1  0.85 441.30 2212121111111110000000000002110 111111112111110 21111111101111111 21112 111121121
S342-1  2.00 441.30 2212121111111110000000000002110 000000002111110 21111111101111121 21111 111212111
S343-1  0.20 442.50 2221111111111110000000000001210 111111112111110 00111111101111121 21111 111212111
S344-1  0.30 442.70 2111111111111110000000000002110 000000000000000 21111111101111121 21111 111121121
S345-1  0.80 443.40 2212121111111110000000000002110 000000000000000 21111111101111111 21112 111212111
S346-1  0.40 443.90 2212111111111110000000000002110 222211112211110 21111111101111111 21111 111212111
S347-1  0.50 444.30 2222111111111110000000000002110 000000000000000 21111111101111111 21111 121112111
S348-1  0.20 444.70 2211111111111110000000000001210 000000000000000 21111111101111111 12211 111211121
S350-1  0.20 445.20 2111111111111110000000000001120 000000002111110 21111111101111111 21111 121112111
S351-1  0.15 445.30 2222111111111111222211111112110 111111112111110 21111111101111111 21112 111212111
S352-1  0.55 445.80 2111111111111110000000000001120 000000002111110 21111111101111111 21111 121112111
S353-1  0.10 446.00 1122221111111111222211111111210 222211112111110 21111111101111111 21111 121112111
S354-1  0.10 446.10 2111111111111110000000000001210 000000012222110 21111111101111111 21111 211112111
S355-1  2.60 447.70 2222111111111111222211111112110 000000002111110 21111111101111111 21111 111212111
S356-1  0.90 449.10 2122221111111111222211111112110 211111112111110 21111111101111111 21111 211112111
S357-1  0.40 449.90 2111111111111110000000000001210 000000002111110 21111111101111111 21111 121112111
S359-1  0.20 450.70 2222111111111111222111111112110 000000012211110 21111111101111111 21111 121112111
S360-1  0.30 451.00 2111111111111110000000000001210 000000012222110 21111111101111111 21111 211112111
S363-1  1.20 452.10 2211111111111110000000000002110 000000000000000 21111111101111111 21112 211112111
S364-1  0.30 451.90 2221111111111110000000000002110 000000000000000 21111111101111121 21111 111212111
S365-1  0.65 453.40 2222111111111110000000000002110 111111112111110 21111111101111121 21111 111212111
S366-1  1.30 454.10 2111111111111110000000000001120 000000000000000 21111111101111111 12211 111212111
S367-1  0.90 455.40 2111111111111110000000000001210 000000000000000 21111111101111111 12211 111212111
S368-1  0.20 456.00 2111111111111110000000000001210 000000000000000 21111111101111111 21111 121112111
S371-1  1.50 456.90 2111111111111110000000000001120 000000002111110 21111111101111111 21112 121112111
S373-1  0.70 459.60 1221111111111110000000000001120 111111112111110 21111111101111121 21111 111212111
S374-1  2.20 461.50 2111111111111110000000000001120 111111112111110 21111111101111111 21111 211112111
S375-1  0.30 462.50 2221111111111110000000000002110 221111112111110 21111111101111121 21111 211112111
S376-1  0.15 462.50 2111111111111110000000000001210 111111112111110 21111111101111111 21111 211112111
S378-1  0.85 463.20 2211111111111110000000000002110 222111112221110 21111111101111111 21111 211112111
S379-1  0.25 463.60 2211111111111110000000000002110 000000002111110 21111111101111111 21112 111211211
S380-1  1.00 463.40 2111111111111110000000000001120 111111112111110 21111111101111121 21111 211112111
S382-1  1.80 466.50 1122221111111111222212111111210 222221112222110 00111111102111211 21111 211112111
S383-1  0.35 467.20 2222111111111111222211111112110 222111112111110 21111111101111121 21111 111212111
S384-1  0.40 467.60 2211111111111110000000000001210 000000002111110 21111111101111111 21111 121112111
S385-1  1.30 468.50 2111111111111110000000000001120 000000002111110 21111111101111111 21111 211112111
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                                                                              X-BED   FOSS    COLOUR
SAMPLE UNIT   METER  GRAIN SIZE      ROUNDNESS SOR       %     %   LWRC    RIP    MC     B FRES WEAT
NAME   THICK  ABOVE                  V   S S   W        DARK  CARB  CNTHLAM      TTUO    AI LDGDR GR
       METER  BASE   1 2 3 4 5 6 7 8 A A A R R RPMW   MINERAL MATR  ESGA   ASCSLPARDN ARPBO GGGYGGGGB
|    | |   | |    | |              ||            || | |       ||     | | ||| || ||    ||| |  || |   || |
S386-1   4.00 472.10 221111111111111000000000001210 000000021111110 21111111101111111 21112 211112111
S387-1   1.50 474.10 112222111111111112222111112110 222221112221110 21111111101111121 21111 111212111
S388-1   4.00 476.60 221111111111111000000000001210 222211112211110 21111111101111111 21112 211112111
S390-1   0.25 481.00 221111111111111000000000002110 000000021111110 21111111101111121 21111 211112111
S391-1   0.25 481.20 111221111111111112221111111120 222221121111110 21111111101111111 21111 211112111
S392-1   2.60 482.80 211111111111111000000000001120 111111121111110 21111111101111111 21112 211112111
S393-1   0.35 481.10 221111111111111000000000001210 000000000000000 21121111101111111 21112 121112111
S394-1   0.70 484.80 222212111111111000000000002110 222211112221110 21112111101111111 21111 111212111
S395-1   0.25 485.10 221111111111111000000000001210 222221112222110 21111111101111111 21111 211112111
S396-1   0.40 485.40 112221111111111112221111112110 222221112211110 21111111101111111 21111 211112111
S397-1   0.25 485.70 221111111111111000000000001210 000000021111110 21111111101111111 21111 211112111
S398-1   0.85 486.30 112222111111111000000000002110 000000021111110 21111111101111111 21112 111212111
S399-1   1.00 486.90 211111111111111000000000001120 000000000000000 12111111101111111 21111 211112111
S400-1   1.45 488.10 211111111111111000000000001120 000000021111110 21111111101111111 21112 111211211
S401-1   2.60 490.70 222211111111111000000000001210 222111112111110 12111111101111111 21111 111211211
S402-1   1.30 492.10 212222111111111122212111112110 222221112221110 12111111101111111 21111 111211211
S403-1   1.60 494.10 222111111111111000000000001210 221111112211110 21111111101111112 21112 111211211
S405-1   1.50 496.50 112222111111111122222111111210 222211112211110 21111111101111111 21111 112112111
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                                                                               X-BED   FOSS    COLOUR
SAMPLE UNIT   METER  GRAIN SIZE       ROUNDNESS  SOR     %       %   LWRC   RIP     MC     D PRES WEAT
NAME   THICK  ABOVE                   V   S S-  W      DARK   CARB   CNTHLAN      TTUO    AI LDGDR GR
       METER  BASE    1 2 3 4 5 6 7 8 A A A R R RPMW  MINERAL MATR   ESGA   ASCSLPARDN ARPBO GGGYGGGGB
|    | |    | |    | |              ||          || | |      ||     | | ||| || ||   ||| |  || |   ||  |
  B1-1   0.80   0.40 1111222211111111222211111112110 222221112222110 21111111101111111 21111 111212111
  B2-1   2.00   1.90 1111222111111111112221111111210 222221112222110 21111111101111111 21111 111212111
  B3-1   1.00   3.40 1121222111111111112222111112110 222221112222110 21111111101111111 21111 111212111
  B4-1   1.00   4.40 1121212221111111122211111112110 222211112222110 21111111101111111 21111 111212111
  B5-1   1.50   5.80 1112221111111111222111111111210 222221112211110 21111111101111111 12211 111212111
  B6-1   0.90   6.90 1111212221111111112221111112110 222211112111110 21111111101111111 21111 111211211
  B7-1   2.00   8.90 1122221111111111112221111112110 222221112211110 12111111101111111 12221 111212111
  B7-2   1.30   9.90 2222111111111112221111111112110 000000012222210 12111111101111111 12221 121112111
  B8-1   0.50  10.70 1122221111111111222211111112110 222211112111110 21111111101111111 21111 111212111
  B9-1   1.20  11.90 1111212221111111122211111111210 222211121111110 21111111101111111 21111 112111211
 B10-1   2.00  13.20 2222111111111111222211111112110 000000012222110 12111111101111111 21111 121112111
 B11-1   1.00  14.80 2221111111111110000000000001210 000000012211110 12111111101111111 21111 121112111
 B12-1   1.40  16.10 1111222111111111122211111111210 222211112111110 21111111101111111 21111 111212111
 B13-1   0.85  17.20 2211111111111110000000000001210 000000012222110 21111111101111111 21111 121112111
 B14-1   2.00  18.40 1122221111111111222211111112110 222221112221110 21111111101111111 21111 111212111
 B15-1   2.30  20.70 2211111111111110000000000001210 000000012221110 12111111101111111 21111 121112111
 B16-1   0.95  22.30 1112221111111111222211111111210 222211112111110 21111111101111111 21111 111212111
 B17-1   0.25  22.80 2211111111111110000000000001120 000000012111110 21111111101111111 21111 121112111
 B18-1   0.65  23.40 2122222111111110000000000002110 000000012221110 21111111102100011 21111 121112111
 B19-1   1.20  24.10 2211111111111110000000000001210 000000012111110 21111111101111112 21111 121112111
 B20-1   1.10  25.20 2211111111111110000000000002110 000000012221110 21121111101111111 21111 121112111
 B21-1   0.15  26.00 2111111111111110000000000001120 000000000000000 21111111101111111 21111 111211211
 B22-1   0.80  26.40 2211111111111110000000000002110 000000012222110 21111111101111111 21111 111211211
 B23-1   0.50  27.10 2211111111111110000000000002110 000000000000000 21111111101111111 21111 111211211
 B25-1   0.20  27.70 2221111111111111122111111112110 000000000000000 21111111101111111 21111 111212111
 B27-1   0.10  27.90 2111111111111110000000000001120 000000000000000 12111111101111111 21111 111211211
 B28-1   0.35  28.20 1122221111111111222111111111210 222211121111110 21111111101111111 21111 111212111
 B29-1   0.60  28.70 2111111111111110000000000001120 000000012111110 21111111101111111 21112 111211211
 B30-1   0.80  29.50 1122211111111111222211111111210 222111121111110 21111111101111111 21111 121112111
 B31-1   0.90  31.50 2222111111111110000000000001210 222221112222110 00121111101111111 21111 111211211
 B32-1   0.75  32.50 2221111111111110000000000001210 222222112222210 21111111101111111 21111 121112111
 B33-1   0.33  33.10 2211111111111110000000000001210 000000000000000 21111111101111111 21111 121112111
 B34-1   0.60  33.60 1122211111111111222111111112110 222221112222110 21121111101111111 21111 111212111
 B36-1   0.55  34.40 2222111111111111222211111111210 222221112222210 21111111101111111 21111 111212111
 B37-1   0.10  34.80 2111111111111110000000000001120 000000000000000 21111111101111111 21111 121112111
 B38-1   0.65  35.10 2222111111111110000000000001210 222111112111110 21111111101111111 21111 111211211
 B39-1   0.75  35.80 2221111111111110000000000001210 222111112221110 21112111101111111 21111 111212111
 B40-1   1.00  36.90 1122211111111111222111111112110 222221112222110 21111111101111111 21111 111212111
 B41-1   1.20  37.50 1111122221111112221111111111210 222222112222210 12111111101111111 12221 111211112
 B42-1   0.10  38.40 1111222111111110000000000001210 000000012222110 21111111101111111 12211 111212111
 B43-1   0.15  38.50 2221111111111110000000000001210 000000000000000 12111111101111111 12111 111212111
 B44-1   0.20  38.60 2211111111111110000000000001210 000000000000000 12111111101111111 21111 111212111
 B45-1   1.10  39.20 2222111111111110000000000002110 000000012222210 21121121101111111 21111 111212111
 B46-1   0.15  40.00 1122211111111111122211111111210 222211112211110 21111111102100011 21111 111212111
 B47-1   0.10  40.10 2222111111111110000000000001210 000000012222110 21111111101111111 21111 121112111
 B49-1   0.20  40.30 2111111111111110000000000001210 000000012222210 21111111102100011 21111 121112111
 B51-1   0.60  41.10 1122221111111111222211111112110 222211112211110 21111111102100011 21111 111211211
 B52-1   0.10  41.40 2211111111111110000000000001210 000000000000000 21111111101111111 21111 111212111
 B53-1   0.10  41.50 1121222111111111222211111111210 222211112211110 21111111101111111 12211 111212111
 B55-1   1.20  42.30 2221111111111110000000000002110 000000012222210 12111111102111111 21111 111212111
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                                                                                  X-BED   FOSS    COLOUR
SAMPLE UNIT   METER  GRAIN SIZE        ROUNDNESS  SOR      %         %     LWBC    RIP       MC       B  FRES WEAT
NAME   THICK  ABOVE                    V   S S    W      DARK      CARB    CNTHLAM         TTUO      AI  LDGDR GR
       METER  BASE    1 2 3 4 5 6 7 8 A A A R R   RPMW  MINERAL    MATR    ESGA    ASCSLPARDN    ARPBO  GGGYGGGGB
|    | |    | |    | |              ||            || | |       ||        | | ||| || ||       ||| |   || |    || |
 B56-1  0.10   43.00 21111111111111100000000000001120 000000000000000 21111111101111111 21111 121112111
 B57-1  1.45   44.10 11222111111111122211111111111210 222221112211110 21111111102111211 21111 111211211
 B59-1  0.55   45.20 11111122211111112222111111111210 222211112111110 21111111101111111 21111 111211211
 B60-1  0.20   45.40 11222211111111112221111111112110 000000012222110 12111111101111111 21111 111212111
 B61-1  0.30   45.70 22221111111111100000000000002110 000000012222110 12111111101111111 21111 121112111
 B62-1  0.45   46.20 11222211111111122211111111112110 000000012222110 21111111101111111 21111 111212111
 B64-1  0.35   46.70 22111111111111100000000000001210 000000000000000 21111111101111111 21111 111212111
 B65-1  0.40   47.10 22221111111111122211111111112110 000000012221111 21111111101111111 21111 111212111
 B66-1  2.00   47.70 11111122211111112221111111111210 222221112111110 00111111101200011 21111 112112111
 B66-2  2.00   51.70 11111122211111112222111111111210 222221112211110 12111111101211111 21111 112112111
 B66-3  1.50   53.70 11112221111111112221111111112110 222211112111110 12111111101200011 21111 112112111
 B67-1  2.00   55.20 11111222111111112222111111112110 222221112221110 21111111101111111 21111 111212111
 B67-2  3.00   57.70 11122211111111112221111111112110 222221112222110 12111111101111111 21111 111212111
 B68-1  2.00   61.20 11111221111111112221111111111120 222211112221110 12111111101111111 21111 111212111
 B69-1  2.00   62.40 11122211111111112221111111111210 222211112211110 12111111101111111 21111 111212111
 B69-2  1.80   64.20 11222211111111112221111111112110 222211112221110 12111111101111111 21111 111212111
 B70-1  0.65   66.10 11222211111111112221111111112110 222211112222110 12111111101111111 21111 111212111
 B71-1  0.30   66.90 22211111111111100000000000002110 000000012222110 21111121101111111 21111 111212111
 B72-1  0.30   67.10 21111111111111100000000000001120 000000000000000 12111111101111111 21111 121112111
 B73-1  0.45   67.50 21222211111111100000000000002110 222211112111110 21111111101111111 21111 111212111
 B74-1  0.10   67.80 22111111111111100000000000001210 000000000000000 21111111101111111 21111 121112111
 B76-1  2.60   71.40 22111111111111100000000000001210 000000000000000 21111111101111111 21111 121112111
 B78-1  3.30   75.20 22111111111111100000000000001210 000000000000000 21111111101111111 21111 121112111
 B79-1  0.35   77.10 21222111111111100000000000002110 000000012222110 21111111101111111 21111 111212111
 B80-1  1.00   77.60 11122211111111112222111111111210 222211112211110 21111111101111111 21111 111212111
 B81-1  2.00   80.50 11222211111111112222111111112110 222211112221110 12111111101111111 21111 111211211
 B82-1  0.30   81.70 12221111111111112221111111111210 222211112221110 21111111101111111 21111 121112111
 B84-1  2.00   82.80 22111111111111100000000000002110 000000012222110 21111111101111111 21111 111212111
 B85-1  1.50   88.50 21111111111111100000000000001120 000000000000000 00111111101111111 21111 111212111
 B86-1  1.30   89.90 11111122211111112221111111111210 222211112221110 21111111101111111 21111 111212111
 B87-1  1.90   93.50 21111111111111100000000000001120 000000000000000 00111111101111111 21111 121112111
 B88-1  0.35   94.50 11222111111111112221111111111210 222111112211110 21111111101111111 21111 111212111
 B89-1  0.60   95.20 11111122211111122211111111112110 222211112211110 21111111101111111 21111 112111211
 B90-1  0.20   95.50 11222211111111122211111111111210 222111112211110 21111111101111111 21111 111212111
 B91-1  0.75   96.10 22111111111111100000000000001210 000000000000000 21111111101111111 12211 121112111
 B92-1  0.45   96.60 11112221111111112221111111112110 222221112221110 21111111101111111 21111 111212111
 B93-1  1.45   97.50 11222111111111112221111111112110 222211112221110 21111111101211211 21111 111212111
 B95-1  0.60   98.40 12221111111111112221111111111210 222211112221110 21111111101111121 21111 111212111
 B97-1  1.00   99.80 11222111111111112221111111111210 222221112221110 21121111101211211 21111 111212111
 B99-1  0.40  100.90 11122211111111112222111111111210 222221112222110 21111111102100011 21111 111212111
B100-1  0.20  101.20 22111111111111100000000000002110 000000000000000 21111111101111111 21111 121112111
B101-1  1.30  101.80 11222211111111112222111111111210 222221112222110 21111111101111111 21111 111211211
B102-1  0.50  102.90 21111111111111100000000000001120 000000000000000 21111111101111111 21111 121112111
B103-1  2.00  104.50 22221111111111112221111111111210 222211112211110 21111111101111111 21111 111212111
B104-1  0.85  106.20 11111122211111112221111111111210 222221112221110 21111111101111111 21111 111211211
B106-1  0.30  107.30 11222111111111112222111111112110 222211112221110 21111111101111111 12211 111211211
B107-1  1.00  108.80 21222211111111112221111111112110 222211112221110 00111111101111121 21111 111211211
B108-1  0.25  111.30 22211111111111100000000000001210 000000000000000 00111111101111111 12211 111211211
B109-1  0.50  111.70 22111111111111100000000000002110 222211100000000 12111111101111111 21111 111211211
B110-1  0.20  112.10 22211111111111100000000000002110 000000000000000 12111111101111111 21111 111211211
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                                                                             X-BED    FOSS    COLOUR
SAMPLE UNIT  METER   GRAIN SIZE      ROUNDNESS  SOR     %        %  LWRC    RIP    MC     B FRES WEAT
NAME   THICK ABOVE                   V   S S   W      DARK    CARB  CNTHLAM      TTUO    AI LDGDR GR
       METER BASE    1 2 3 4 5 6 7 8 A A A R R RPMW  MINERAL MATR   ESGA   ASCSLPARDN ARPBO GGGYGGGGB
|    | |   | |    | |              ||          || |  |      ||    | | ||| || ||    ||| |  || |    || |
B111-1  0.70 113.50 2111111111111110000000000001120 111111121111110 00111111101111111 21112 121112111
B112-1  0.30 114.10 2222121111111111222211111112110 222211112211110 21111111101111111 21111 111211211
B113-1  1.80 115.20 2111111111111110000000000001120 111111121111110 00111111101111111 21112 121112111
B114-1  1.00 116.50 1111111122222111112221111111210 222211112111110 00111111101111111 21111 111211211
B115-1  3.00 119.00 2211111111111110000000000001210 000000000000000 21111111101111111 21111 121112111
B116-1  1.00 120.50 1111111122221111112221111111210 222211121111110 21111111101211211 21111 111211211
B117-1  1.90 122.10 1111111122222121112221111112110 222221112221110 21111111101111111 21111 111211211
B118-1  0.50 123.20 1111111122222121112221111112110 222221112221110 21111111101111111 21111 111211211
B119-1  2.00 123.80 1111111221111111112221111111210 222221112211110 21111111101111111 21111 111211211
B119-2  1.00 125.00 1111112221111111112221111111210 222221112211110 12111111101111111 21111 111211211
B120-1  1.00 126.80 1111111122211111112221111111210 222221121111110 21111111101111111 21111 111211211
B121-1  0.40 127.60 1111112122211111112221111112110 222211112111110 21111111101111121 21111 111211211
B122-1  1.20 128.50 1111111121222211112222111112110 222211112111110 21111111101111121 21111 111211211
B123-1  0.40 129.20 1111111122222111112222111112110 222211112211110 21111111101111121 21111 111211211
B124-1  0.70 129.80 1111111122222111112221111112110 222221112211110 21111111101111121 12221 111211211
B125-1  1.00 130.80 1111122211111111112222111112110 222221112221110 21111111101111121 21111 111211211
B126-1  2.00 131.10 1111112222111111112222111112110 222221112221110 21111111101111111 21111 111211211
B126-2  0.80 133.10 1111111222111111112221111112110 222211112221110 21111111101111111 21111 111211211
B127-1  2.00 133.90 1111112221111111122211111111210 222221112222110 21111111101111111 12221 111211211
B127-2  2.00 135.90 1111112221111111122211111112110 222221112211110 12111111101111111 21111 111211211
B127-3  2.00 137.90 1111112221111111122211111112110 222221112111110 12111111101111111 21111 111211211
B127-4  2.00 139.90 1111112221111111112222111111210 222211112111110 12111111101111111 21111 111211211
B127-5  2.00 141.90 1111112221111111112221111112110 222221112221110 12111111101111111 21111 112111211
B127-6  2.00 143.90 1111112221111111122211111112110 222221112111110 12111111101111111 21111 111211211
B127-7  2.00 145.90 1111212221111111122211111112110 222222112222110 12111111101111111 21111 111211211
B127-8  2.00 147.90 1111122211111111122221111112110 222221112211110 12111111101111111 21111 112111211
B128-1  1.10 150.50 1111112221111111112221111112110 222211112211110 21111111101211211 21111 111211211
B129-1  0.05 151.00 2222121111111110000000000002110 000000012221110 21111211101111111 21111 121112111
B130-1  0.50 151.30 2111111111111110000000000001120 000000000000000 21111111101111111 21111 121112111
B131-1  0.20 151.60 1111222111111111122221111112110 222221112211110 11211111101211211 21111 111211211
B131-2  2.00 153.50 1111122211111111122211111112110 222221112221110 12111111101211211 21111 111211211
B131-3  0.20 155.50 1111222111111111122211111112110 222211112211110 12111111101211211 21111 111211211
B132-1  1.50 156.80 1111112221111111112222111112110 222211121111110 21111111101211211 21111 112111211
B133-1  0.70 157.40 1122221111111111122221111112110 222111112211110 21111111101111111 12111 111211211
B134-1  0.85 158.40 2222111111111110000000000002110 000000012221110 12111111101111111 21111 121112111
B135-1  0.90 159.30 2211111111111110000000000001210 000000000000000 12121121101111111 21111 121112111
B137-1  0.10 160.10 2221111111111110000000000001210 221111112111110 21111111101111111 21111 111211211
B138-1  0.45 160.40 1122211111111111122211111112110 222211112221110 21111111101111111 21111 111211211
B139-1  0.40 160.50 2221111111111110000000000002110 000000012221110 21111111101111111 21111 121112111
B140-1  1.55 161.80 2211111111111110000000000001210 000000012211110 21111111101111111 21111 121112111
B141-1  0.40 162.80 1111112221111111112221111111210 222211112111110 21111111101211211 21111 112111211
B142-1  2.00 162.90 1111112221111111112221111111210 222211112211110 21111111101211211 11111 112112111
B142-2  1.00 164.90 1111112221111111122411111112110 222211112221110 12111111101211211 21111 112112111
B143-1  0.20 166.10 1111111222111111122211111112110 222221112221110 21111111101111111 12211 112111211
B144-1  1.70 166.90 1111112222111111222221111112110 222211112221110 21111111101211221 12211 112111211
B145-1  0.53 168.20 1111222211111111122211111112110 222221112221110 21111111102111211 12211 112111211
B146-1  1.10 169.20 1111112222111111122211111112110 222211112221110 21111111101211211 21111 111212111
B147-1  0.65 169.90 1111222111111111112222111111210 222211112111110 21111111102111211 21111 111212111
B148-1  2.00 170.10 1111222211111111122211111112110 222211112221110 21111111101211211 21111 112112111
B148-2  1.50 173.90 1111112221111111112221111112110 222221112221110 12111111101211211 12211 111212111
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                                                                                      X-BED   POSS    COLOUR
SAMPLE UNIT   METER  GRAIN SIZE         ROUNDNESS  SOR     %       %      LWRC    BIP     MC      B  FRES WEAT
NAME   THICK  ABOVE                     V   S S    W      DARK    CARB    CNTHLAM         TTUO   AI  LDGDR GR
       METER  BASE    1 2 3 4 5 6 7 8 A A A ? R  RPMW   MINERAL  MATR    ESGA    ASCSLPARDN ARPBO GGGYGGGGB
|    | |    | |     | |              ||          || | |            ||    | | ||| || ||      ||| |  || |    || |
B148-3  0.50 173.90 1111112221111111222211111112110 222221112222110 12111111102111211 21111 111212111
B149-1  0.50 174.30 1111122211111111122211111111210 222211121111110 21111111101111111 21111 111212111
B150-1  2.00 174.60 1111122211111111122211111112110 222221112211110 21111111101111111 21111 112111211
B150-2  2.00 176.50 1111122211111111122211111111210 222221112221110 12111111101111111 21111 112111211
B151-1  2.00 176.90 1111122211111111122211111111210 222221112221110 21111111101200011 21111 112112111
B151-2  0.20 178.90 1111122211111111122211111112110 222211112221110 12111111101200011 21111 112112111
B152-1  0.90 179.80 1122221111111111122211111112110 222221112211110 12111111101111111 21111 112112111
B153-1  0.40 180.20 1222121111111111122211111112110 222221112222110 21121111101111111 21111 111212111
B154-1  2.10 182.50 2211111111111111000000000001210 000000000000000 21111121101111111 21111 121112111
B156-1  0.80 183.40 2221111111111111000000000001210 000000000000000 12111111101111111 12111 121112111
B157-1  3.65 186.20 2111111111111111000000000001120 000000000000000 21111121101111111 21111 121112111
B158-1  1.00 187.80 2211111111111111000000000001120 000000012221110 21111111101111111 21111 111211211
B160-1  0.40 189.20 2221111111111111000000000001210 000000012221110 21111111101111111 21111 121112111
B161-1  5.15 192.40 2211111111111111000000000001120 000000012211110 21111121101111111 21111 111211211
B163-1  0.50 195.20 2221111111111111000000000001210 000000012222110 12111111101111111 21111 111211211
B164-1  0.30 195.60 2111111111111111000000000001120 000000000000000 21111111101111111 12111 111211211
B165-1  0.50 196.10 2122211111111111000000000002110 000000000000000 21111111101111111 21111 111211211
B166-1  0.10 196.30 2222111111111111000000000002110 000000000000000 12111111101111111 21111 111211211
B167-1  1.00 196.90 2211111111111111000000000001210 000000012211110 12111111101111111 21111 111211211
B168-1  0.20 197.40 1122211111111111122211111112110 222211112221110 21111111101111121 21111 111212111
B169-1  0.34 197.60 2222111111111111122211111112110 222211112221110 12111111101111111 21111 111212111
B170-1  2.00 197.90 1111112221111112221111111111210 222221112221110 21111111101211221 12211 112112111
B170-2  1.28 199.80 1111112222111111222211111112110 222221112211110 12111111101211211 12211 112112111
B171-1  0.60 201.50 1122221111111111122211111112110 222221112222110 00111111101111121 21111 111211211
B173-1  0.10 202.40 2221111111111111000000000001210 000000012222110 21111111101111111 21112 111212111
B174-1  1.70 203.50 2111111111111111000000000001120 000000000000000 21111111101111111 21111 111211211
B175-1  0.60 204.30 1111222111111111000000000001210 000000000000000 00111111101111121 21111 111211211
B176-1  0.20 206.60 2221111111111111000000000002110 000000000000000 00111111101111121 21112 121112111
B177-1  2.40 208.30 2111111111111111000000000001210 000000021111110 21111111101111111 21112 111211211
B178-1  0.90 211.50 2221111111111111000000000001210 000000012221110 00111111101111111 21111 121112111
B180-1  1.20 212.50 2111111111111111000000000001120 000000000000000 21111111101111111 21111 112111211
B181-1  0.35 213.60 2211111111111111000000000002110 000000012221110 21111111101111111 21112 121112111
B182-1  0.15 213.80 2111111111111111000000000001120 000000012222110 21121112101111111 21111 121111211
B183-1  0.80 214.20 1111222211111111222211111112110 222211112211110 21111111101200011 21111 112112111
B184-1  0.08 214.70 2222121111111111000000000002110 000000012211110 21111111101111111 21111 111212111
B186-1  0.60 215.10 1111222111111111122211111112110 222221112221110 21111111101111111 21111 112112111
B187-1  0.50 215.70 2111111111111111000000000001120 000000012222110 21111111101111111 12111 111211211
B189-1  1.00 217.50 2211111111111111000000000001210 000000012222110 21111111101111111 21111 121112111
B191-1  0.25 219.70 2111111111111111000000000001120 000000000000000 21111111101111111 21111 111211211
B192-1  1.00 220.40 2211111111111111000000000001210 000000012222110 21111111101111111 21111 111212111
B193-1  1.00 221.40 2111111111111111000000000001120 000000000000000 21111111101111111 21111 111212111
B194-1  0.85 222.30 1122211111111111122211111111210 222211112211110 21111111101111111 21111 111212111
B195-1  0.40 222.90 2222111111111111000000000002110 000000012221110 21111111101111111 21111 111212111
B196-1  0.80 223.40 1111222111111111122221111112110 222211112221110 21111111102111111 21111 111211112
B197-1  1.45 224.80 2111111111111111000000000001120 000000021111110 21111111101111111 21111 112111211
B198-1  1.70 226.50 2221111111111111000000000002110 000000012211110 12111111101111121 21111 111211211
B199-1  0.35 227.20 2111111111111111000000000001120 000000021111110 12111111101111111 21111 111211211
B200-1  0.60 227.50 2221111111111111000000000002110 000000012111110 21121111101111111 21111 111212111
B201-1  0.35 228.20 2211111111111111000000000001210 000000012211110 12111111101111111 21111 111212111
B202-1  1.40 231.50 2221111111111111000000000001210 000000012111110 21111111101111111 21111 111212111
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                                                                            X-BED   FOSS    COLOUR
SAMPLE UNIT   METER  GRAIN SIZE      ROUNDNESS  SOR     %      %      LWRC   BIP     MC       B FRES WEAT
NAME   THICK  ABOVE                  V   S S    W      DARK   CARB    CNTHLAM        TTUO    AI LDGDR GR
       METER  BASE   1 2 3 4 5 6 7 8 A A A R R  RPHW  MINERAL MATR    ESGA   ASCSLPARDN ARPDO GGGYGGGGB
|    | |    | |    | |              ||          || |  |        ||   | | ||| || ||    ||| |   || |    || |
B203-1  0.75 232.50 2111111111111111000000000000001120 000000000000000 21111111101111111 21111 111211211
B204-1  0.90 233.60 1111112221111111122211111111210 222211121111110 21111111101111111 21111 112112111
B205-1  0.60 234.20 1111112221111111122211111111210 222211112111110 21111111101111111 21111 112112111
B206-1  0.40 234.40 1111122111111111122211111111210 222111121111110 21111111101111111 21111 211112111
B207-1  0.90 235.20 1111112221111111122211111112110 222211112111110 21111111101111111 21111 211112111
B208-1  0.60 236.10 1111222111111111122211111112110 000000021111110 12111111101111111 21111 112112111
B209-1  0.30 238.10 1122221211111111000000000000002110 000000012221110 00111111101111121 21111 121112111
```

APPENDIX C.

TRANSITION MATRICES FOR THE MEASURED SECTIONS

Abbreviations used in Appendix C:

clay	claystone
silt	siltstone
v.f.	very fine grained sandstone
fine	fine grained sandstone
med+	medium grained sandstone to conglomerate

TYPE SECTION ** COMPLETE BLAIRMORE GROUP

EMBEDDED MARKOV CHAIN ** GRAIN SIZE LITHOLOGIES

Transition frequency matrix:

	clay	silt	v.f.	fine	med+
clay	0	24	12	13	4
silt	21	0	11	4	5
v.f.	19	8	0	5	5
fine	13	3	7	0	4
med+	4	2	6	5	0

n = 175

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.45	0.23	0.25	0.08
silt	0.51	0.00	0.27	0.10	0.12
v.f.	0.51	0.22	0.00	0.14	0.14
fine	0.48	0.11	0.26	0.00	0.15
med+	0.24	0.12	0.35	0.29	0.00

$\chi^2_{\text{observed}} = 110.833$ $\chi^2_{(.001,\ 11)} = 31.3$

Independent events matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.31	0.30	0.23	0.16
silt	0.43	0.00	0.26	0.20	0.13
v.f.	0.41	0.27	0.00	0.20	0.13
fine	0.39	0.25	0.24	0.00	0.12
med+	0.36	0.23	0.23	0.17	0.00

Difference matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.14	-0.07	0.02	-0.08
silt	0.08	0.00	0.01	-0.10	-0.01
v.f.	0.10	-0.05	0.00	-0.06	0.01
fine	0.11	-0.14	0.02	0.00	0.03
med+	-0.12	-0.11	0.12	0.12	0.00

TYPE SECTION ** COMPLETE BLAIRMORE GROUP

REGULAR MARKOV CHAIN ** GRAIN SIZE LITHOLOGIES

1 METRE SAMPLE INTERVAL

Transition frequency matrix:

	clay	silt	v.f.	fine	med+
clay	50	15	6	7	6
silt	9	37	6	5	4
v.f.	12	6	37	2	4
fine	7	3	3	33	3
med+	2	2	3	5	45

n = 312

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.60	0.18	0.07	0.08	0.07
silt	0.15	0.61	0.10	0.08	0.07
v.f.	0.20	0.10	0.61	0.03	0.07
fine	0.14	0.06	0.06	0.67	0.06
med+	0.04	0.04	0.05	0.09	0.79

2 METRE SAMPLE INTERVAL

Transition frequency matrix:

	clay	silt	v.f.	fine	med+
clay	14	10	4	4	2
silt	3	13	3	3	1
v.f.	6	2	13	3	5
fine	1	4	4	10	3
med+	2	4	3	5	24

n = 146

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.41	0.29	0.12	0.12	0.06
silt	0.13	0.57	0.13	0.13	0.04
v.f.	0.21	0.07	0.45	0.10	0.17
fine	0.05	0.18	0.18	0.45	0.14
med+	0.05	0.11	0.08	0.13	0.63

TYPE SECTION ** COMPLETE BLAIRMORE GROUP

EMBEDDED MARKOV CHAIN ** LITHOTYPES

Transition frequency matrix:

	T1	T2	T3	T4	T5
T1	0	20	11	14	6
T2	16	0	10	2	4
T3	21	5	0	8	4
T4	11	2	6	0	7
T5	6	5	5	5	0

n = 168

Transition probability matrix:

	T1	T2	T3	T4	T5
T1	0.00	0.39	0.22	0.27	0.12
T2	0.50	0.00	0.31	0.06	0.21
T3	0.55	0.13	0.00	0.21	0.11
T4	0.42	0.08	0.23	0.00	0.27
T5	0.29	0.24	0.24	0.24	0.00

Independent events matrix:

	T1	T2	T3	T4	T5
T1	0.00	0.28	0.28	0.26	0.18
T2	0.40	0.00	0.24	0.21	0.15
T3	0.41	0.24	0.00	0.21	0.15
T4	0.38	0.23	0.23	0.00	0.15
T5	0.38	0.23	0.23	0.21	0.00

Difference matrix:

	T1	T2	T3	T4	T5
T1	0.00	0.11	0.06	0.01	-0.06
T2	0.10	0.00	0.07	-0.15	-0.02
T3	0.14	-0.11	0.00	0.00	-0.04
T4	0.04	-0.15	0.00	0.00	0.08
T5	-0.09	0.01	0.01	0.03	0.00

$\chi^2_{\text{observed}} = 106.448$ $\chi^2_{(.001,\ 11)} = 31.3$

TYPE SECTION ** COMPLETE BALIRMORE GROUP

REGULAR MARKOV CHAIN ** LITHOTYPES

1 METRE SAMPLE INTERVAL

Transition frequency matrix:

	T1	T2	T3	T4	T5
T1	81	13	7	11	6
T2	11	35	9	0	4
T3	13	4	24	7	3
T4	10	2	5	21	8
T5	4	5	5	7	63

n = 358

Transition probability matrix:

	T1	T2	T3	T4	T5
T1	0.69	0.11	0.06	0.09	0.05
T2	0.19	0.59	0.15	0.00	0.07
T3	0.25	0.08	0.47	0.14	0.06
T4	0.22	0.04	0.11	0.46	0.17
T5	0.05	0.06	0.06	0.08	0.75

2 METRE SAMPLE INTERVAL

Transition frequency matrix:

	T1	T2	T3	T4	T5
T1	16	11	13	5	4
T2	9	13	5	2	2
T3	11	3	6	4	5
T4	5	1	4	9	5
T5	3	2	5	5	17

n = 165

Transition probability matrix:

	T1	T2	T3	T4	T5
T1	0.33	0.22	0.27	0.10	0.08
T2	0.29	0.42	0.16	0.06	0.06
T3	0.38	0.10	0.21	0.14	0.17
T4	0.21	0.04	0.17	0.38	0.21
T5	0.09	0.06	0.16	0.16	0.53

TYPE SECTION ** BEAVER MINES FORMATION

EMBEDDED MARKOV CHAIN ** GRAIN SIZE LITHOLOGIES

Transition frequency matrix:

	clay	silt	v.f.	fine	med+
clay	0	22	7	10	4
silt	13	0	9	2	3
v.f.	13	7	0	3	3
fine	9	0	5	0	3
med+	5	0	4	4	0

n = 120

Independent events matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.33	0.31	0.21	0.15
silt	0.40	0.00	0.26	0.20	0.13
v.f.	0.40	0.28	0.00	0.19	0.13
fine	0.37	0.27	0.23	0.00	0.12
med+	0.35	0.26	0.22	0.17	0.00

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.51	0.16	0.23	0.09
silt	0.48	0.00	0.33	0.07	0.11
v.f.	0.50	0.27	0.00	0.12	0.12
fine	0.53	0.00	0.29	0.00	0.18
med+	0.38	0.00	0.31	0.31	0.00

Difference matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.18	-0.15	0.02	-0.06
silt	0.08	0.00	0.07	-0.13	-0.02
v.f.	0.10	-0.01	0.00	-0.07	-0.01
fine	0.24	-0.27	0.06	0.00	0.06
med+	0.03	-0.26	0.09	0.14	0.00

$\chi^2_{\text{observed}} = 98.550$ $\chi^2_{(.001,\ 11)} = 31.3$

TYPE SECTION ** BEAVER MINES FORMATION
REGULAR MARKOV CHAIN ** GRAIN SIZE LITHOLOGIES

1 METRE SAMPLE INTERVAL

Transition frequency matrix:

	clay	silt	v.f.	fine	med+
clay	33	12	5	4	6
silt	8	29	6	3	2
v.f.	9	5	8	3	3
fine	6	1	4	10	3
med+	1	0	2	4	24

n = 191

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.55	0.20	0.08	0.07	0.10
silt	0.17	0.60	0.13	0.06	0.04
v.f.	0.32	0.18	0.29	0.11	0.11
fine	0.25	0.04	0.17	0.42	0.13
med+	0.03	0.00	0.06	0.13	0.79

2 METRE SAMPLE INTERVAL

Transition frequency matrix:

	clay	silt	v.f.	fine	med+
clay	8	6	7	4	1
silt	10	7	3	1	0
v.f.	6	3	1	0	6
fine	1	1	3	6	1
med+	1	1	2	4	7

n = 90

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.31	0.23	0.27	0.15	0.04
silt	0.48	0.33	0.14	0.05	0.00
v.f.	0.38	0.19	0.06	0.00	0.38
fine	0.08	0.08	0.25	0.50	0.08
med+	0.07	0.07	0.13	0.27	0.47

TYPE SECTION ** BEAVER MINES FORMATION

EMBEDDED MARKOV CHAIN ** LITHOTYPES

Transition frequency matrix:

	TBM1	TBM2	TBM3	TBM4	TBM5	TBM6
TBM1	0	9	3	4	4	8
TBM2	3	0	6	2	7	6
TBM3	0	4	0	4	1	5
TBM4	3	5	2	0	1	5
TBM5	5	3	4	1	0	1
TBM6	16	5	4	4	0	0

n = 124

Transition probability matrix:

	TBM1	TBM2	TBM3	TBM4	TBM5	TBM6
TBM1	0.00	0.32	0.11	0.14	0.14	0.29
TBM2	0.13	0.00	0.25	0.08	0.29	0.25
TBM3	0.00	0.29	0.00	0.29	0.07	0.36
TBM4	0.19	0.31	0.13	0.00	0.06	0.31
TBM5	0.36	0.21	0.29	0.07	0.00	0.07
TBM6	0.55	0.17	0.14	0.14	0.00	0.00

Independent events matrix:

	TBM1	TBM2	TBM3	TBM4	TBM5	TBM6
TBM1	0.00	0.27	0.20	0.15	0.13	0.26
TBM2	0.27	0.00	0.19	0.15	0.13	0.26
TBM3	0.25	0.24	0.00	0.14	0.12	0.24
TBM4	0.25	0.24	0.17	0.00	0.12	0.23
TBM5	0.25	0.24	0.15	0.14	0.00	0.23
TBM6	0.27	0.26	0.29	0.15	0.13	0.00

Difference matrix:

	TBM1	TBM2	TBM3	TBM4	TBM5	TBM6
TBM1	0.00	0.05	-0.09	-0.01	0.01	0.04
TBM2	-0.14	0.00	0.06	-0.07	0.16	-0.01
TBM3	-0.25	0.05	0.00	0.15	-0.05	0.12
TBM4	-0.06	0.07	-0.04	0.00	-0.06	0.08
TBM5	0.11	-0.03	0.14	-0.07	0.00	-0.16
TBM6	0.28	-0.09	-0.05	-0.01	-0.13	0.00

$\chi^2_{\text{observed}} = 89.761$, $\chi^2_{(.001,\ 19)} = 43.8$

TYPE SECTION ** BEAVER MINES FORMATION

REGULAR MARKOV CHAIN ** LITHOTYPES

1 METRE SAMPLE INTERVAL

Transition frequency matrix:

	TBM1	TBM2	TBM3	TBM4	TBM5	TBM6
TBM1	30	7	2	4	3	4
TBM2	3	12	3	3	6	6
TBM3	1	3	5	3	0	3
TBM4	3	6	3	37	1	2
TBM5	2	4	1	2	18	1
TBM6	11	2	3	3	0	16

n = 213

Transition probability matrix:

	TBM1	TBM2	TBM3	TBM4	TBM5	TBM6
TBM1	0.60	0.14	0.04	0.08	0.06	0.08
TBM2	0.09	0.36	0.09	0.09	0.18	0.18
TBM3	0.07	0.20	0.33	0.20	0.00	0.20
TBM4	0.06	0.12	0.06	0.71	0.02	0.04
TBM5	0.07	0.14	0.04	0.07	0.64	0.04
TBM6	0.31	0.06	0.09	0.09	0.00	0.46

2 METRE SAMPLE INTERVAL

Transition frequency matrix:

	TBM1	TBM2	TBM3	TBM4	TBM5	TBM6
TBM1	13	3	1	1	2	3
TBM2	1	1	3	6	1	2
TBM3	1	3	2	2	0	1
TBM4	3	4	2	15	0	2
TBM5	2	3	0	0	3	0
TBM6	5	3	2	1	0	4

n = 95

Transition probability matrix:

	TBM1	TBM2	TBM3	TBM4	TBM5	TBM6
TBM1	0.57	0.13	0.04	0.04	0.09	0.13
TBM2	0.07	0.07	0.21	0.43	0.07	0.14
TBM3	0.11	0.33	0.22	0.22	0.00	0.11
TBM4	0.12	0.15	0.08	0.58	0.00	0.08
TBM5	0.25	0.38	0.00	0.00	0.38	0.00
TBM6	0.33	0.20	0.13	0.07	0.00	0.27

SHEEP RIVER SECTION ** COMPLETE BLAIRMORE GROUP

EMBEDDED MARKOV CHAIN ** GRAIN SIZE LITHOTYPES

Transition frequency matrix:

	clay	silt	v.f.	fine	med+
clay	0	53	28	9	3
silt	62	0	17	5	2
v.f.	23	20	0	1	5
fine	10	3	2	0	2
med+	4	5	2	2	0

n = 258

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.57	0.30	0.10	0.03
silt	0.72	0.00	0.20	0.06	0.02
v.f.	0.47	0.41	0.00	0.02	0.10
fine	0.59	0.18	0.12	0.00	0.12
med+	0.31	0.38	0.15	0.15	0.00

Independent events matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.50	0.31	0.11	0.08
silt	0.57	0.00	0.27	0.09	0.07
v.f.	0.47	0.39	0.00	0.08	0.06
fine	0.41	0.34	0.20	0.00	0.05
med+	0.40	0.33	0.20	0.07	0.00

Difference matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.07	-0.01	-0.01	0.05
silt	0.15	0.00	-0.07	-0.03	-0.05
v.f.	0.00	0.02	0.00	-0.06	0.04
fine	0.18	-0.16	-0.08	0.00	0.07
med+	-0.09	0.05	-0.05	0.08	0.00

$\chi^2_{\text{observed}} = 204.231$ $\chi^2_{(.001,\ 11)} = 31.3$

SHEEP RIVER SECTION ** COMPLETE BLAIRMORE GROUP

REGULAR MARKOV CHAIN ** GRAIN SIZE LITHOLOGIES

1 METRE SAMPLE INTERVAL

Transition frequency matrix:

	clay	silt	v.f.	fine	med+
clay	104	23	16	4	5
silt	26	46	14	1	2
v.f.	15	14	23	4	2
fine	7	0	3	13	3
med+	3	7	1	2	19

n = 357

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.68	0.15	0.11	0.03	0.03
silt	0.29	0.52	0.16	0.01	0.02
v.f.	0.26	0.24	0.40	0.07	0.03
fine	0.27	0.00	0.12	0.50	0.12
med+	0.09	0.22	0.03	0.06	0.59

2 METRE SAMPLE INTERVAL

Transition frequency matrix:

	clay	silt	v.f.	fine	med+
clay	41	18	9	3	2
silt	14	21	16	3	1
v.f.	11	10	6	1	2
fine	5	0	1	2	2
med+	1	3	2	2	12

n = 188

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.56	0.25	0.12	0.04	0.03
silt	0.25	0.38	0.29	0.05	0.02
v.f.	0.37	0.33	0.20	0.03	0.07
fine	0.50	0.00	0.10	0.20	0.20
med+	0.05	0.15	0.10	0.10	0.60

SHEEP RIVER SECTION ** COMPLETE BLAIRMORE GROUP

EMBEDDED MARKOV CHAIN ** LITHOTYPES

Transition frequency matrix:

	S1	S2	S3	S4	S5	S6
S1	0	17	13	7	6	11
S2	12	0	18	5	12	9
S3	10	19	0	3	2	5
S4	10	1	8	0	10	6
S5	13	5	3	8	0	6
S6	12	9	2	13	3	0

n = 258

Independent events matrix:

	S1	S2	S3	S4	S5	S6
S1	0.00	0.25	0.22	0.18	0.16	0.18
S2	0.28	0.00	0.22	0.17	0.16	0.17
S3	0.26	0.23	0.00	0.17	0.15	0.18
S4	0.26	0.23	0.20	0.00	0.15	0.16
S5	0.26	0.23	0.20	0.15	0.00	0.16
S6	0.25	0.22	0.20	0.18	0.15	0.00

Transition probability matrix:

	S1	S2	S3	S4	S5	S6
S1	0.00	0.31	0.24	0.13	0.11	0.20
S2	0.21	0.00	0.32	0.09	0.21	0.16
S3	0.26	0.49	0.00	0.08	0.05	0.13
S4	0.29	0.03	0.23	0.00	0.29	0.17
S5	0.37	0.14	0.09	0.23	0.00	0.17
S6	0.31	0.23	0.05	0.33	0.08	0.00

Difference matrix:

	S1	S2	S3	S4	S5	S6
S1	0.00	0.06	0.02	-0.06	-0.05	0.02
S2	-0.07	0.00	0.10	-0.08	0.05	-0.01
S3	0.00	0.26	0.00	-0.09	-0.10	-0.05
S4	0.03	-0.20	0.03	0.00	0.14	0.01
S5	0.11	-0.09	-0.11	0.08	0.00	0.01
S6	0.06	0.01	-0.15	0.15	-0.07	0.00

$\chi^2_{observed} = 156.610$ $\chi^2_{(.001,\ 19)} = 43.8$

SHEEP RIVER SECTION ** COMPLETE BALIRMORE GROUP

REGULAR MARKOV CHAIN ** LITHOTYPES

1 METRE SAMPLE INTERVAL

Transition frequency matrix:

	S1	S2	S3	S4	S5	S6
S1	40	8	4	5	2	7
S2	7	32	7	2	6	6
S3	4	5	11	3	2	2
S4	5	1	4	22	5	4
S5	4	4	2	5	18	5
S6	8	6	2	8	2	48

n = 306

Transition probability matrix:

	S1	S2	S3	S4	S5	S6
S1	0.61	0.12	0.06	0.08	0.03	0.11
S2	0.12	0.53	0.12	0.03	0.10	0.10
S3	0.15	0.19	0.41	0.11	0.07	0.07
S4	0.12	0.02	0.10	0.54	0.12	0.10
S5	0.11	0.11	0.05	0.13	0.47	0.13
S6	0.11	0.08	0.03	0.11	0.03	0.65

2 METRE SAMPLE INTERVAL

Transition frequency matrix:

	S1	S2	S3	S4	S5	S6
S1	17	8	4	3	2	5
S2	8	8	3	3	4	3
S3	2	1	3	1	3	2
S4	5	0	1	10	3	3
S5	3	3	2	3	7	3
S6	4	6	2	3	1	5

n = 143

Transition probability matrix:

	S1	S2	S3	S4	S5	S6
S1	0.44	0.21	0.10	0.08	0.05	0.13
S2	0.29	0.29	0.11	0.07	0.14	0.11
S3	0.17	0.08	0.25	0.08	0.25	0.17
S4	0.23	0.00	0.05	0.45	0.14	0.14
S5	0.14	0.14	0.10	0.14	0.33	0.14
S6	0.19	0.29	0.10	0.14	0.05	0.24

SHEEP RIVER SECTION ** BEAVER MINES FORMATION

EMBEDDED MARKOV CHAIN ** GRAIN SIZE LITHOLOGIES

Transition frequency matrix:

	clay	silt	v.f.	fine	med+
clay	0	23	13	6	3
silt	28	0	6	2	1
v.f.	10	8	0	1	2
fine	5	2	2	0	2
med+	2	3	0	2	0

n = 121

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.51	0.29	0.13	0.07
silt	0.76	0.00	0.16	0.05	0.03
v.f.	0.48	0.38	0.00	0.05	0.10
fine	0.45	0.18	0.18	0.00	0.18
med+	0.29	0.43	0.00	0.29	0.00

Independent events matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.47	0.28	0.14	0.11
silt	0.54	0.00	0.25	0.12	0.09
v.f.	0.45	0.36	0.00	0.11	0.08
fine	0.40	0.35	0.18	0.00	0.07
med+	0.39	0.33	0.18	0.10	0.00

Difference matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.04	0.01	0.01	-0.04
silt	0.22	0.00	-0.09	-0.07	-0.07
v.f.	0.03	0.02	0.00	-0.06	0.02
fine	0.05	-0.17	0.00	0.00	0.11
med+	-0.10	0.10	-0.18	0.19	0.00

$\chi^2_{\text{observed}} = 96.935$ $\chi^2_{(.001,\ 11)} = 31.3$

SHEEP RIVER SECTION ** BEAVER MINES FORMATION

REGULAR MARKOV CHAIN ** GRAIN SIZE LITHOLOGIES

1 METRE SAMPLE INTERVAL

Transition frequency matrix:

	clay	silt	v.f.	fine	med+
clay	57	12	10	4	2
silt	15	20	5	1	1
v.f.	8	5	17	3	1
fine	4	1	1	15	3
med+	2	3	0	2	16

n = 208

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.67	0.14	0.12	0.05	0.02
silt	0.36	0.48	0.12	0.02	0.02
v.f.	0.24	0.15	0.50	0.09	0.03
fine	0.17	0.04	0.04	0.63	0.13
med+	0.09	0.13	0.00	0.09	0.70

2 METRE SAMPLE INTERVAL

Transition frequency matrix:

	clay	silt	v.f.	fine	med+
clay	19	8	6	2	1
silt	8	6	7	1	1
v.f.	8	4	5	1	1
fine	2	1	1	4	1
med+	0	3	0	0	9

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.53	0.22	0.17	0.06	0.03
silt	0.35	0.26	0.30	0.04	0.04
v.f.	0.42	0.21	0.26	0.05	0.05
fine	0.22	0.11	0.11	0.44	0.11
med+	0.00	0.25	0.00	0.00	0.75

SHEEP RIVER SECTION ** BEAVER MINES FORMATION

EMBEDDED MARKOV CHAIN ** LITHOTYPES

Transition frequency matrix:

	SBM1	SBM2	SBM3	SBM4	SBM5	SBM6	SBM7
SBM1	0	0	1	3	4	4	7
SBM2	0	0	1	3	2	1	2
SBM3	0	3	0	0	2	0	1
SBM4	3	0	1	0	2	2	7
SBM5	4	3	1	3	0	8	9
SBM6	6	1	1	1	9	0	1
SBM7	3	5	0	7	8	2	0

n = 121

Transition probability matrix:

	SBM1	SBM2	SBM3	SBM4	SBM5	SBM6	SBM7
SBM1	0.00	0.00	0.05	0.16	0.21	0.21	0.37
SBM2	0.00	0.00	0.11	0.33	0.22	0.11	0.22
SBM3	0.00	0.50	0.00	0.00	0.33	0.00	0.17
SBM4	0.20	0.00	0.07	0.00	0.13	0.13	0.47
SBM5	0.14	0.11	0.04	0.11	0.00	0.29	0.32
SBM6	0.32	0.05	0.05	0.05	0.47	0.00	0.05
SEM7	0.12	0.20	0.00	0.28	0.32	0.08	0.00

$\chi^2_{observed} = 94.914$ $\chi^2_{(.001,\ 29)} = 58.3$

Independent events matrix:

	SBM1	SBM2	SBM3	SBM4	SBM5	SBM6	SBM7
SBM1	0.00	0.19	0.04	0.15	0.24	0.15	0.24
SBM2	0.14	0.00	0.04	0.16	0.25	0.16	0.25
SBM3	0.13	0.18	0.00	0.14	0.22	0.14	0.22
SBM4	0.14	0.19	0.04	0.00	0.25	0.15	0.25
SBM5	0.18	0.24	0.06	0.19	0.00	0.19	0.30
SBM6	0.14	0.19	0.04	0.15	0.24	0.00	0.24
SBM7	0.15	0.21	0.04	0.17	0.28	0.17	0.00

Difference matrix:

	SBM1	SBM2	SBM3	SBM4	SBM5	SBM6	SBM7
SBM1	0.00	-0.19	0.01	0.01	-0.03	-0.06	0.13
SBM2	-0.14	0.00	0.07	0.17	-0.03	-0.05	-0.03
SBM3	-0.13	0.32	0.00	-0.14	0.11	-0.14	-0.05
SBM4	0.06	-0.19	0.03	0.00	-0.12	-0.02	0.22
SBM5	-0.04	-0.13	-0.02	-0.08	0.00	0.10	0.02
SBM6	0.22	-0.14	0.01	-0.11	0.23	0.00	0.19
SBM7	0.03	0.01	-0.04	0.11	-0.04	-0.09	0.00

SHEEP RIVER SECTION ** BEAVER MINES FORMATION

REGULAR MARKOV CHAIN ** LITHOTYPES

1 METRE SAMPLE INTERVAL

Transition frequency matrix:

	SBM1	SBM2	SBM3	SBM4	SBM5	SBM6	SBM7
SBM1	14	2	0	2	3	4	5
SBM2	0	21	2	2	3	0	1
SBM3	0	2	15	0	2	0	1
SBM4	2	0	1	9	0	2	5
SBM5	7	2	1	2	17	4	5
SBM6	6	1	1	1	4	21	1
SBM7	1	2	0	3	7	2	24

n = 210

Transition probability matrix:

	SBM1	SBM2	SBM3	SBM4	SBM5	SBM6	SBM7
SBM1	0.47	0.07	0.00	0.07	0.10	0.13	0.17
SBM2	0.00	0.72	0.07	0.07	0.10	0.00	0.03
SBM3	0.00	0.10	0.75	0.00	0.10	0.00	0.05
SBM4	0.11	0.00	0.05	0.47	0.00	0.11	0.26
SBM5	0.18	0.05	0.03	0.05	0.45	0.11	0.13
SBM6	0.17	0.03	0.03	0.03	0.11	0.60	0.03
SBM7	0.03	0.05	0.00	0.08	0.18	0.05	0.62

2 METRE SAMPLE INTERVAL

Transition frequency matrix:

	SBM1	SBM2	SBM3	SBM4	SBM5	SBM6	SBM7
SBM1	2	1	0	1	3	3	3
SBM2	0	8	0	2	3	0	0
SBM3	0	0	7	0	1	0	1
SBM4	1	0	1	4	2	1	2
SBM5	5	1	2	1	3	2	5
SBM6	2	2	0	0	4	7	7
SBM7	3	1	0	3	1	1	9

n = 105

Transition probability matrix:

	SBM1	SBM2	SBM3	SBM4	SBM5	SBM6	SBM7
SBM1	0.15	0.08	0.00	0.-8	0.23	0.23	0.23
SBM2	0.00	0.62	0.00	0.15	0.23	0.00	0.00
SBM3	0.00	0.00	0.78	0.00	0.11	0.00	0.11
SBM4	0.09	0.00	0.09	0.36	0.18	0.09	0.18
SBM5	0.26	0.05	0.11	0.05	0.16	0.11	0.26
SBM6	0.09	0.09	0.00	0.00	0.18	0.32	0.32
SBM7	0.17	0.06	0.00	0.17	0.06	0.06	0.50

BURNT TIMBER CREEK SECTION ** BEAVER MINES FORMATION

EMBEDDED MARKOV CHAIN ** GRAIN SIZE LITHOLOGIES

Transition frequency matrix:

	clay	silt	v.f.	fine	med+
clay	0	15	14	5	5
silt	25	0	7	3	1
v.f.	10	13	0	0	6
fine	2	3	4	0	6
med+	1	2	6	9	0

n = 136.

Independent events matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.34	0.31	0.17	0.17
silt	0.37	0.00	0.31	0.16	0.16
v.f.	0.36	0.32	0.00	0.17	0.17
fine	0.32	0.27	0.26	0.00	0.15
med+	0.32	0.28	0.2[illegible]	0.14	0.00

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.38	0.36	0.13	0.13
silt	0.69	0.00	0.19	0.08	0.03
v.f.	0.36	0.46	0.00	0.00	0.18
fine	0.13	0.20	0.27	0.00	0.40
med+	0.06	0.11	0.33	0.50	0.00

Difference matrix:

	clay	silt	v.f.	fine	med+
clay	0.00	0.04	0.05	-0.04	-0.04
silt	0.32	0.00	-0.19	-0.08	-0.13
v.f.	0.00	0.14	0.00	-0.17	0.01
fine	-0.19	-0.07	0.01	0.00	0.25
med+	-0.26	-0.17	0.07	0.36	0.00

$\chi^2_{\text{observed}} = 124.497$ $\chi^2_{(.001,\ 11)} = 31.3$

BURNT TIMBER CREEK SECTION ** BEAVER MINES FORMATION

REGULAR MARKOV CHAIN ** GRAIN SIZE LITHOLOGIES

1 METRE SAMPLE INTERVAL

Transition frequency matrix:

	clay	silt	v.f.	fine	med+
clay	29	7	8	2	5
silt	11	6	5	1	1
v.f.	7	6	10	1	5
fine	1	1	3	24	6
med+	3	2	4	5	36

n = 189

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.57	0.14	0.16	0.04	0.10
silt	0.46	0.25	0.21	0.04	0.04
v.f.	0.24	0.21	0.34	0.03	0.17
fine	0.03	0.03	0.09	0.69	0.17
med+	0.06	0.04	0.08	0.10	0.72

2 METRE SAMPLE INTERVAL

Transition freqeuncy matrix:

	clay	silt	v.f.	fine	med+
clay	11	3	4	2	2
silt	3	0	2	2	4
v.f.	5	4	6	0	1
fine	2	1	5	9	1
med+	0	1	2	5	14

n = 89

Transition probability matrix:

	clay	silt	v.f.	fine	med+
clay	0.50	0.14	0.18	0.09	0.09
silt	0.27	0.00	0.18	0.18	0.36
v.f.	0.31	0.25	0.38	0.00	0.06
fine	0.11	0.06	0.28	0.50	0.06
med+	0.00	0.05	0.09	0.23	0.64

BURNT TIMBER CREEK SECTION ** BEAVER MINES FORMATION

EMBEDDED MARKOV CHAIN ** LITHOTYPES

Transition frequency matrix:

	B1	B2	B3	B4	B5
B1	0	3	4	1	1
B2	3	0	6	2	4
B3	3	2	0	17	12
B4	0	3	9	0	16
B5	4	5	13	10	0

r = 118

Transition probability matrix:

	B1	B2	B3	B4	B5
B1	0.00	0.33	0.44	0.11	9.11
B2	0.20	0.00	0.40	0.13	0.27
B3	0.09	0.06	0.00	0.50	0.35
B4	0.00	0.11	0.32	0.00	0.57
B5	0.13	0.16	0.41	0.31	0,00

$\chi^2_{observed} = 87.257$ $\chi^2_{(.001,\ 11)} = 31.3$

Independent events matrix:

	B1	B2	B3	B4	B5
B1	0.00	0.12	0.30	0.28	0.30
B2	0.10	0.00	0.30	0.29	0.31
B3	0.11	0.15	0.00	0.36	0.38
B4	0.11	0.14	0.37	0.00	0.38
B5	0.12	0.16	0.37	0.35	0.00

Difference matrix:

	B1	B2	B3	B4	B5
B1	0.00	0.21	0.14	-0.17	-0.19
B2	0.10	0.00	0.10	-0.16	-0.04
B3	-0.02	-0.09	0.00	0.14	-0.03
B4	-0.11	-0.03	-0.05	0.00	0.19
B5	0.01	0.00	0.04	-0.04	0.00

BURNT TIMBER CREEK SECTION ** BEAVER MUNES FORMATION

REGULAR MARKOV CHAIN ** LITHOTYPES

1 METRE SAMPLE INTERVAL

Transition frequency matrix:

	B1	B2	B3	B4	B5
B1	42	3	3	0	2
B2	3	19	3	2	3
B3	2	2	18	7	8
B4	0	2	6	13	9
B5	3	2	8	9	31

n = 200

Transition probability matrix:

	B1	B2	B3	B4	B5
B1	0.84	0.06	0.06	0.00	0.04
B2	0.10	0.63	0.10	0.07	0.10
B3	0.05	0.05	0.49	0.19	0.22
B4	0.00	0.07	0.20	0.43	0.30
B5	0.06	0.04	0.15	0.17	0.58

2 METRE SAMPLE INTERVAL

Transition frequency matrix:

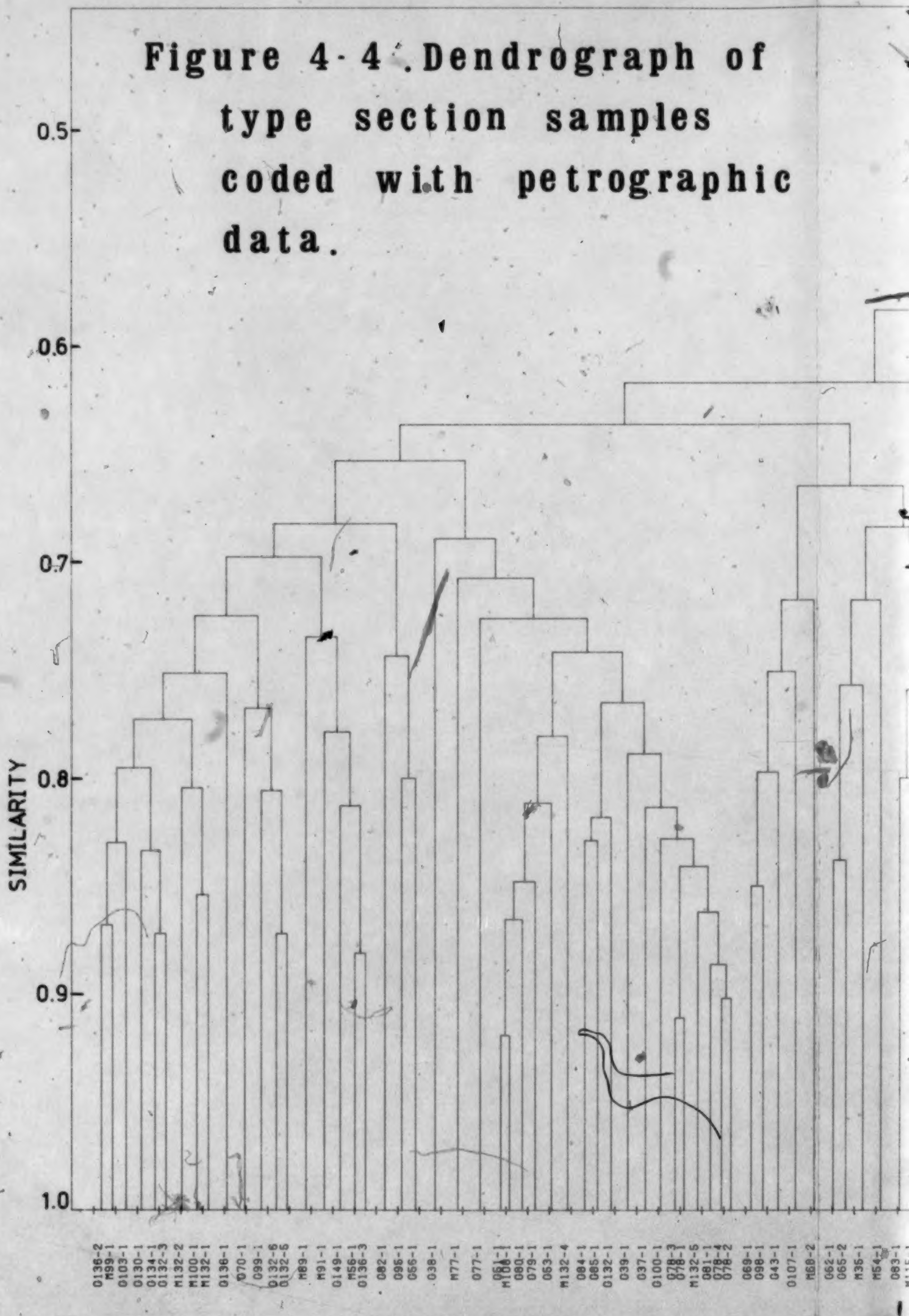
	B1	B2	B3	B4	B5
B1	22	2	1	1	2
B2	2	5	3	2	2
B3	2	0	7	5	5
B4	1	3	4	3	6
B5	1	2	5	8	7

n = 103

Transition proability matrix:

	B1	B2	B3	B4	B5
B1	0.79	0.07	0.04	0.04	0.07
B2	0.14	0.36	0.21	0.14	0.14
B3	0.11	0.00	0.37	0.26	0.26
B4	0.06	0.18	0.24	0.18	0.35
B5	0.04	0.09	0.22	0.35	0.30

Figure 4·4. Dendrograph of type section samples coded with petrographic data.



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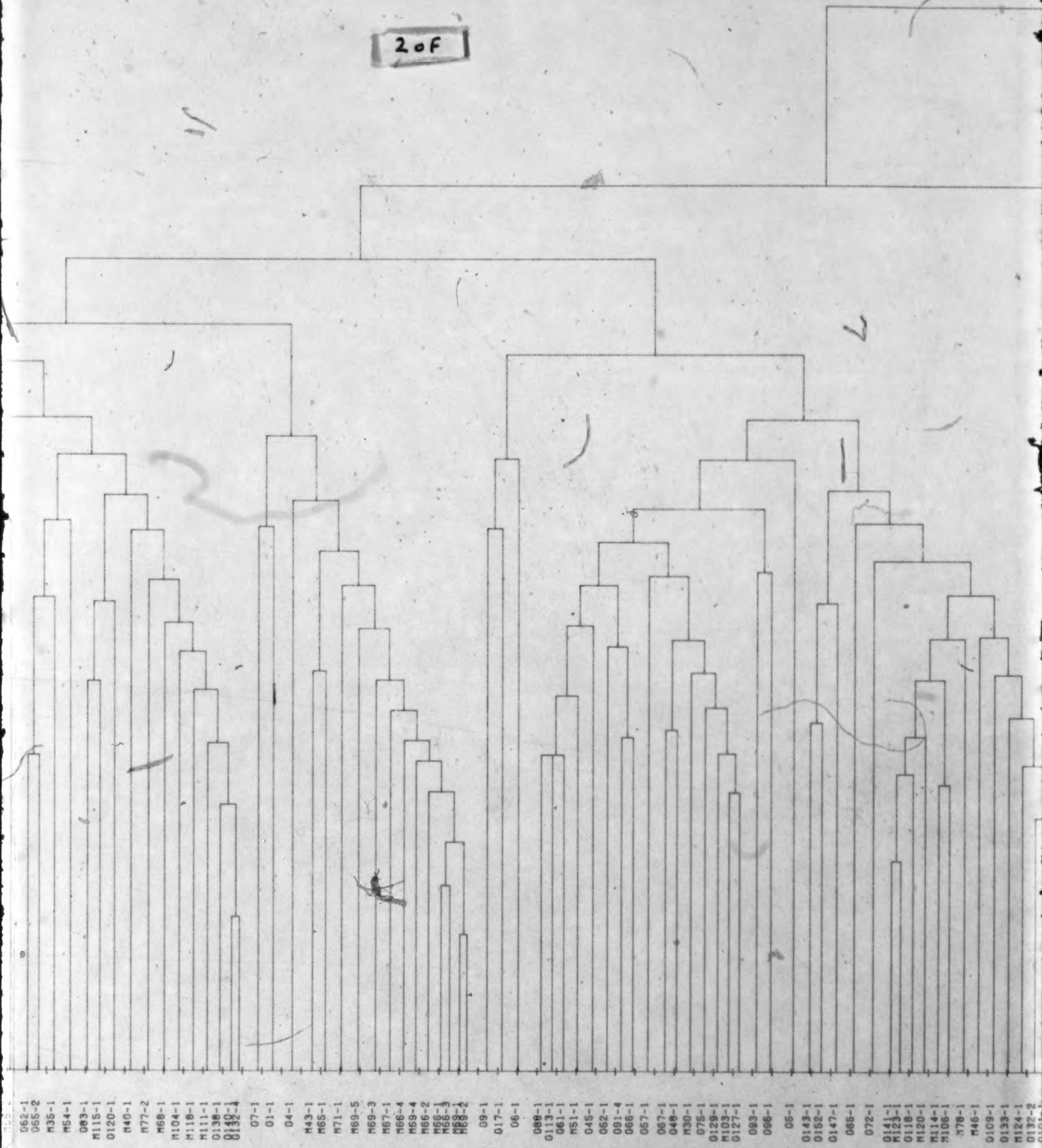
2oF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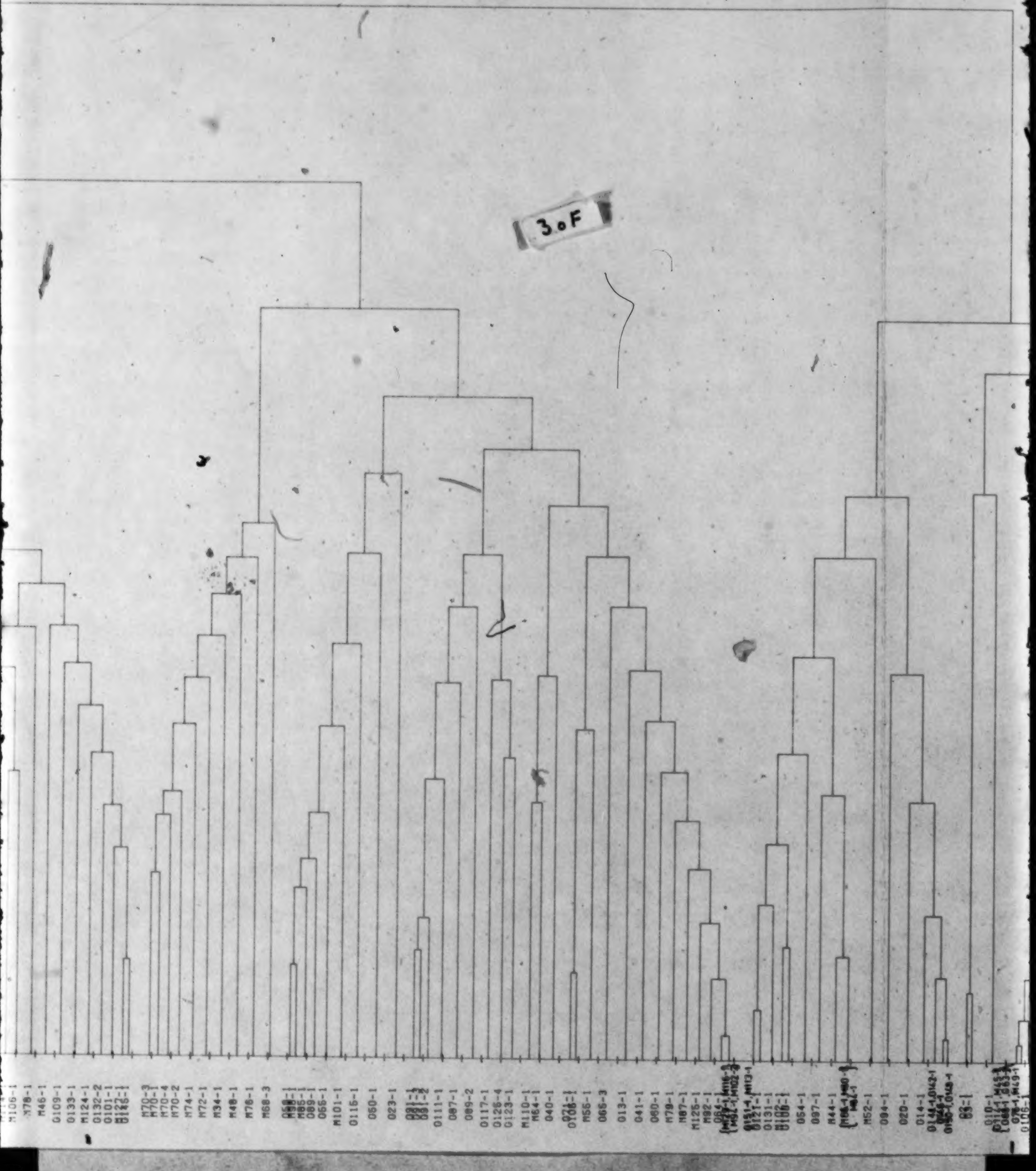
3oF



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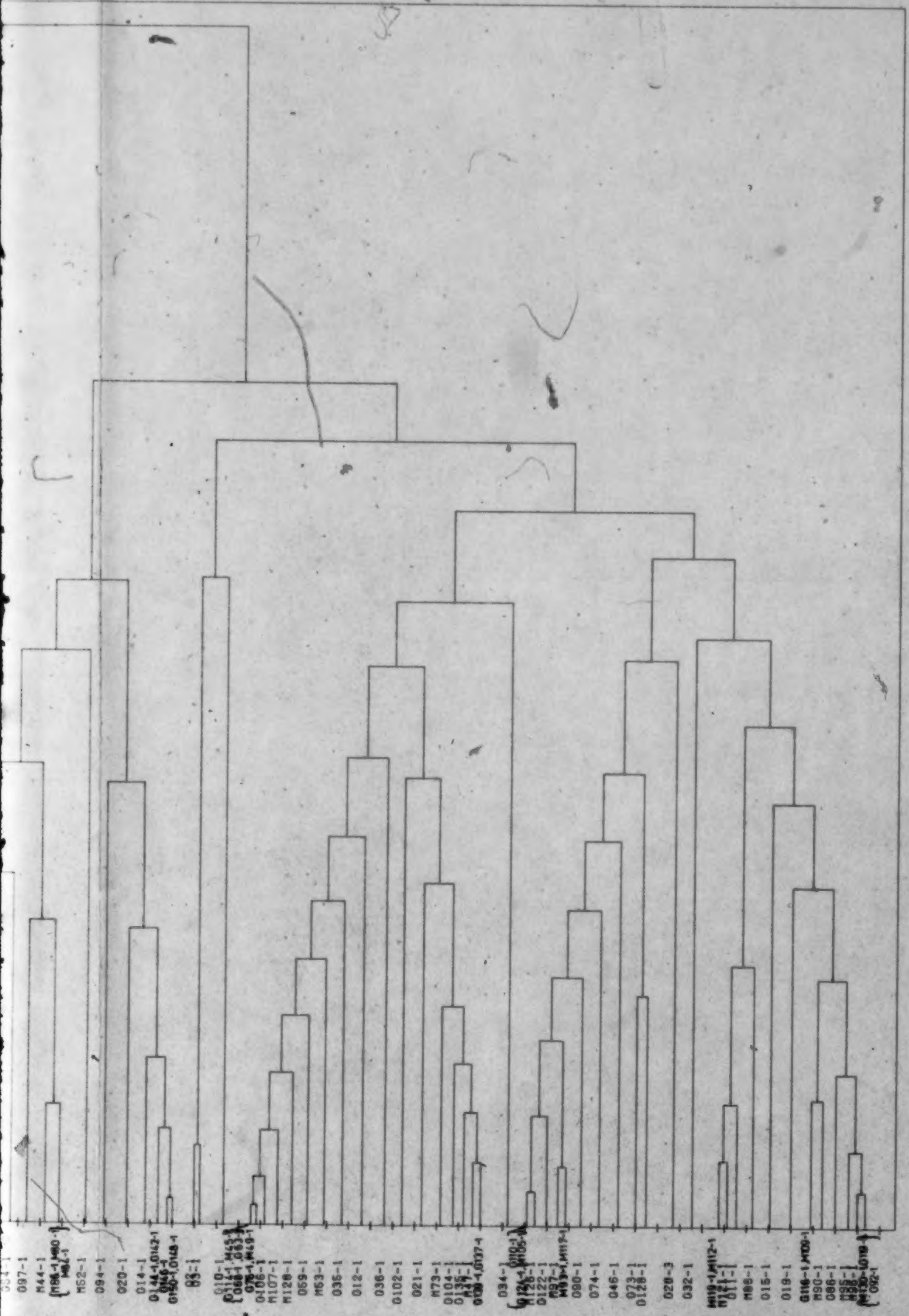
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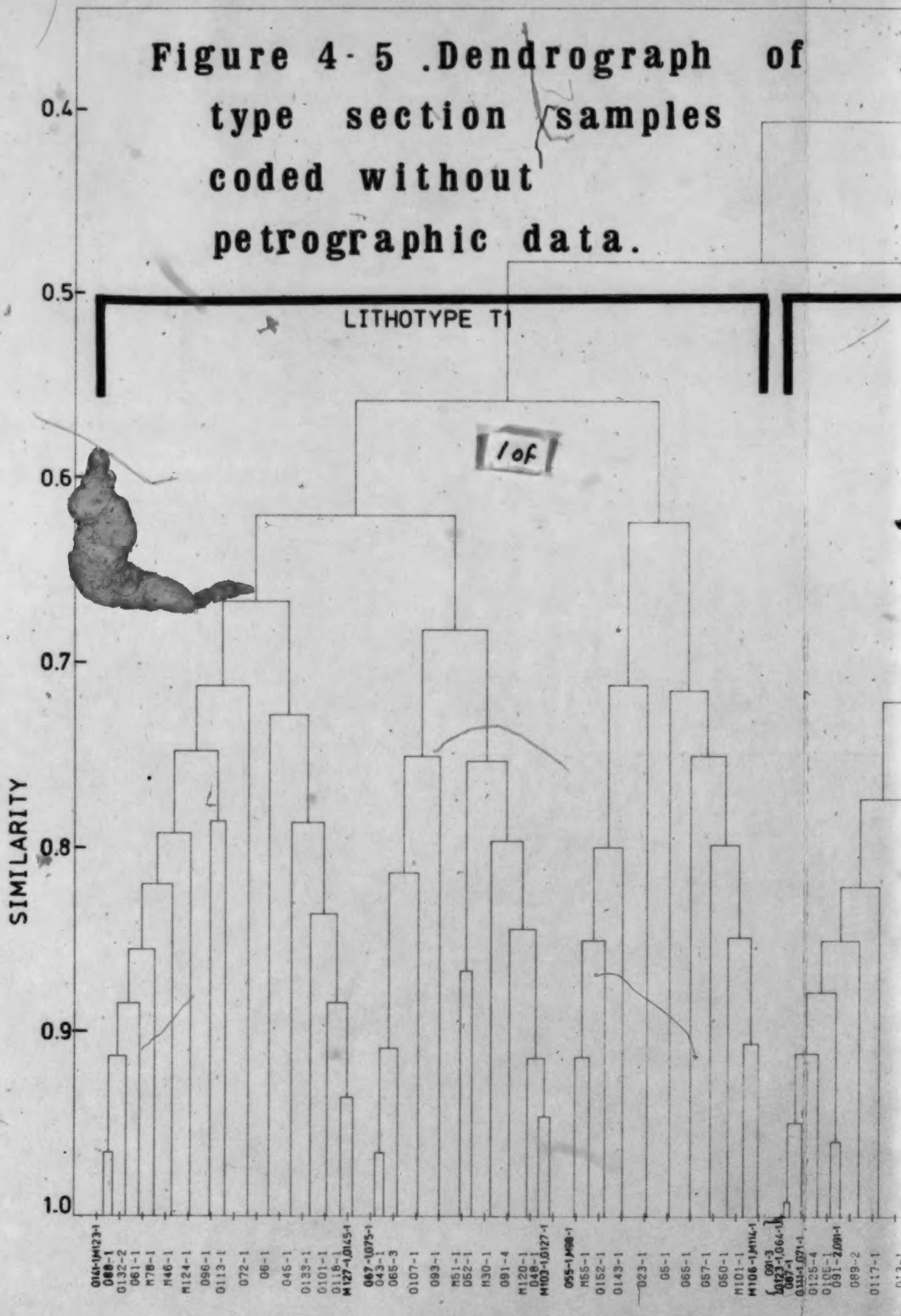

Figure 4-5 .Dendrograph of type section samples coded without petrographic data.

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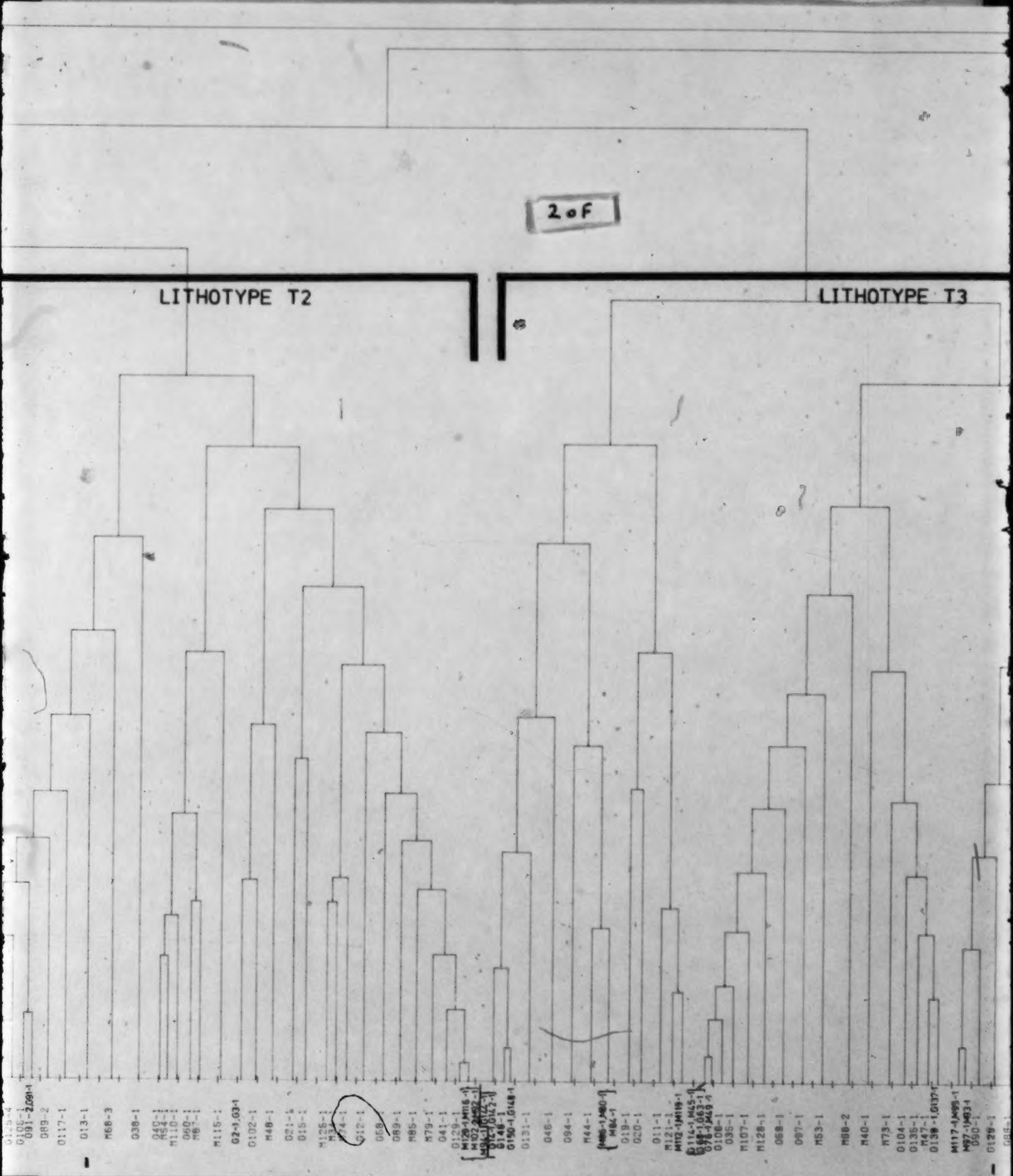
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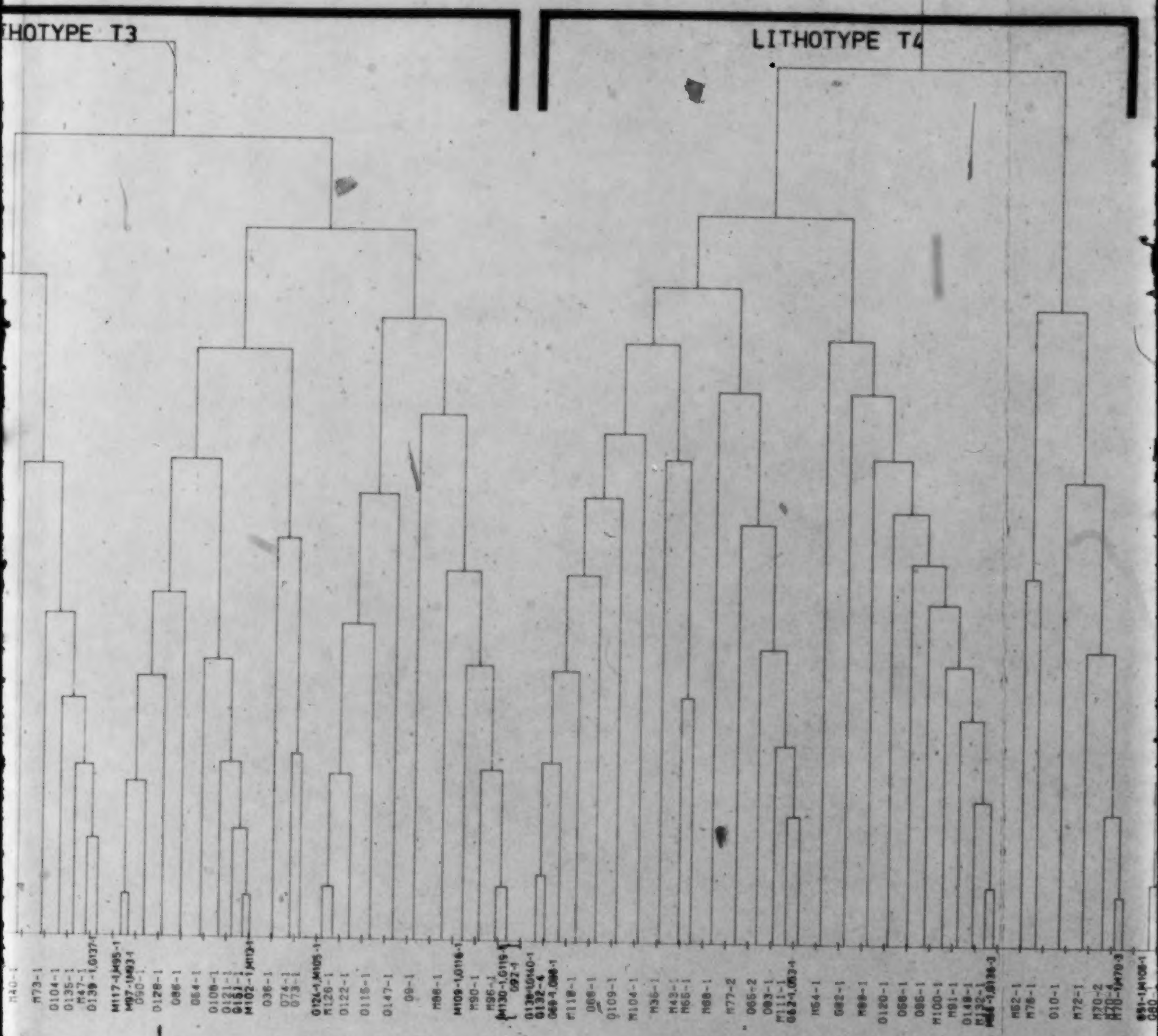
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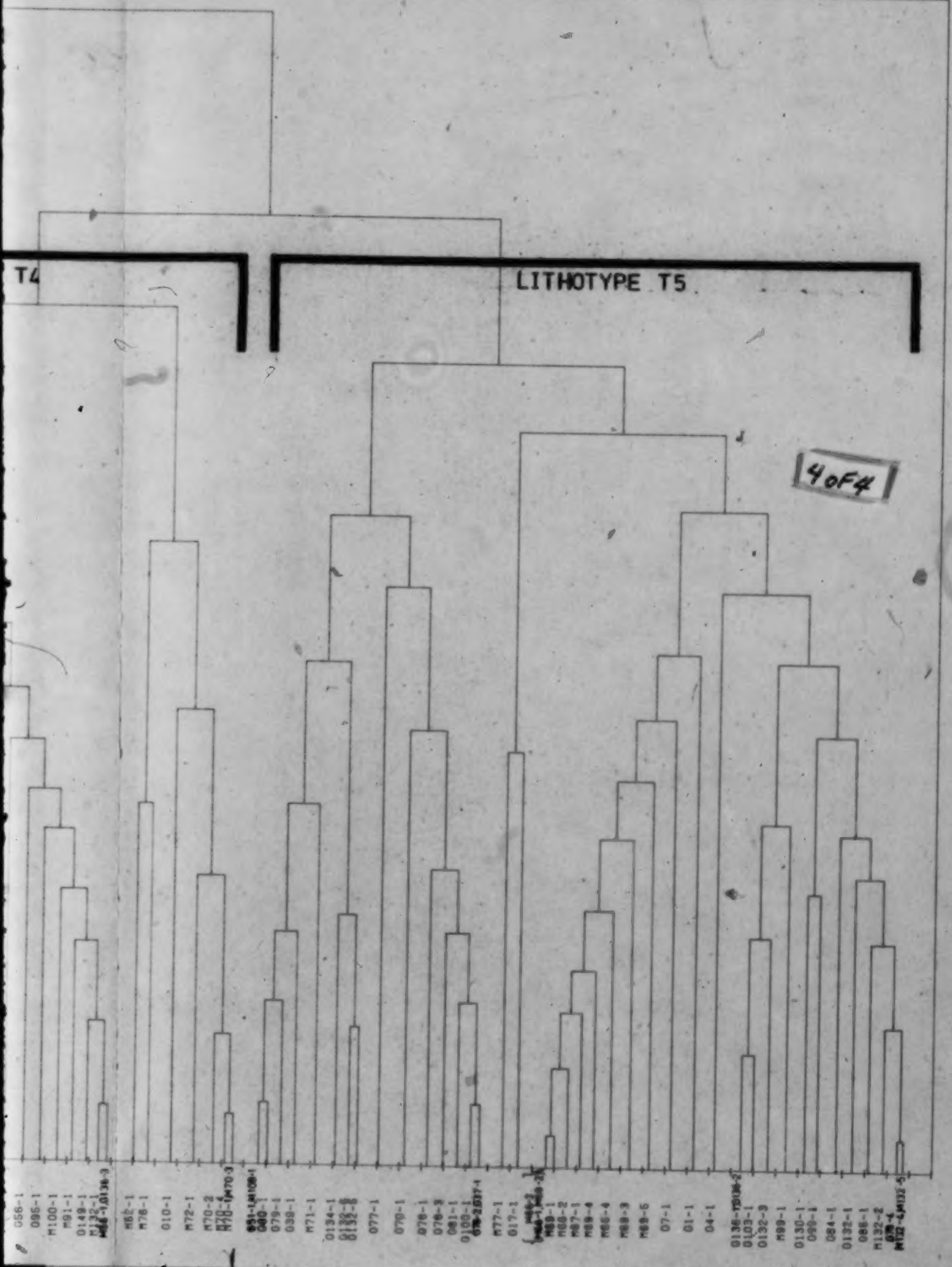
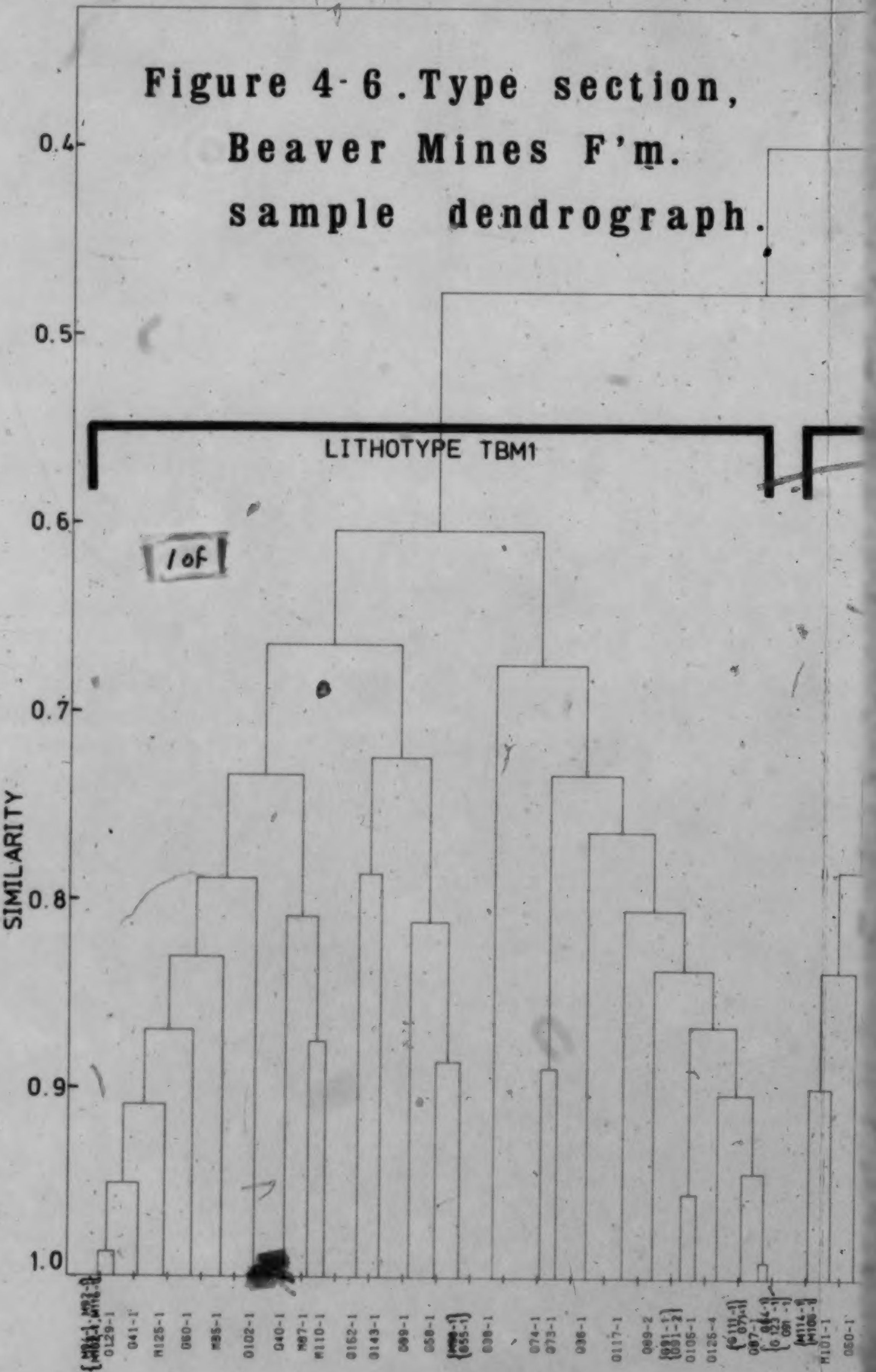
O139-1,O137-1
M117-1,M95-1
M97-1,M93-1
O90-1
O128-1
O86-1
O64-1
O108-1
O121-1
O151-1
M102-1,M113-1
O36-1
O74-1
O73-1
O124-1,M105-1
M126-1
O122-1
O115-1
O147-1
O9-1
M98-1
M109-1,O116-1
M90-1
M96-1
M130-1,O119-1
O92-1
O138-1,O140-1
O132-4
O69-1,O88-1
M110-1
O68-1
O109-1
M104-1
M36-1
M43-1
M65-1
M88-1
M77-2
O65-2
O83-1
M111-1
O82-1,O63-4
M54-1
O82-1
M99-1
O120-1
O58-1
O95-1
M100-1
M91-1
O149-1
M132-1
M88-1,O136-3
M52-1
M76-1
O10-1
M72-1
M70-2
M70-4
M78-1,M70-3
O51-1,M108-1
O80-1


T4
LITHOTYPE T5
056-1
095-1
M100-1
M91-1
0149-1
M132-1
M66-1,0136-3
M82-1
M76-1
010-1
M72-1
M70-2
M70-4
M70-1,M70-3
051-1,M100-1
040-1
079-1
039-1
M71-1
0134-1
0132-6
0132-5
077-1
070-1
078-1
078-3
081-1
0100-1
078-2,037-1
M77-1
017-1
M89-1
M89-1
M88-2
M87-1
M89-4
M86-4
M89-3
M89-5
07-1
01-1
04-1
0136-1,0136-2
0103-1
0132-3
M99-1
0130-1
099-1
084-1
0132-1
088-1
M132-2
070-4
M132-4,M132-5

4 of 4

Figure 4-6. Type section, Beaver Mines F'm. sample dendrograph.



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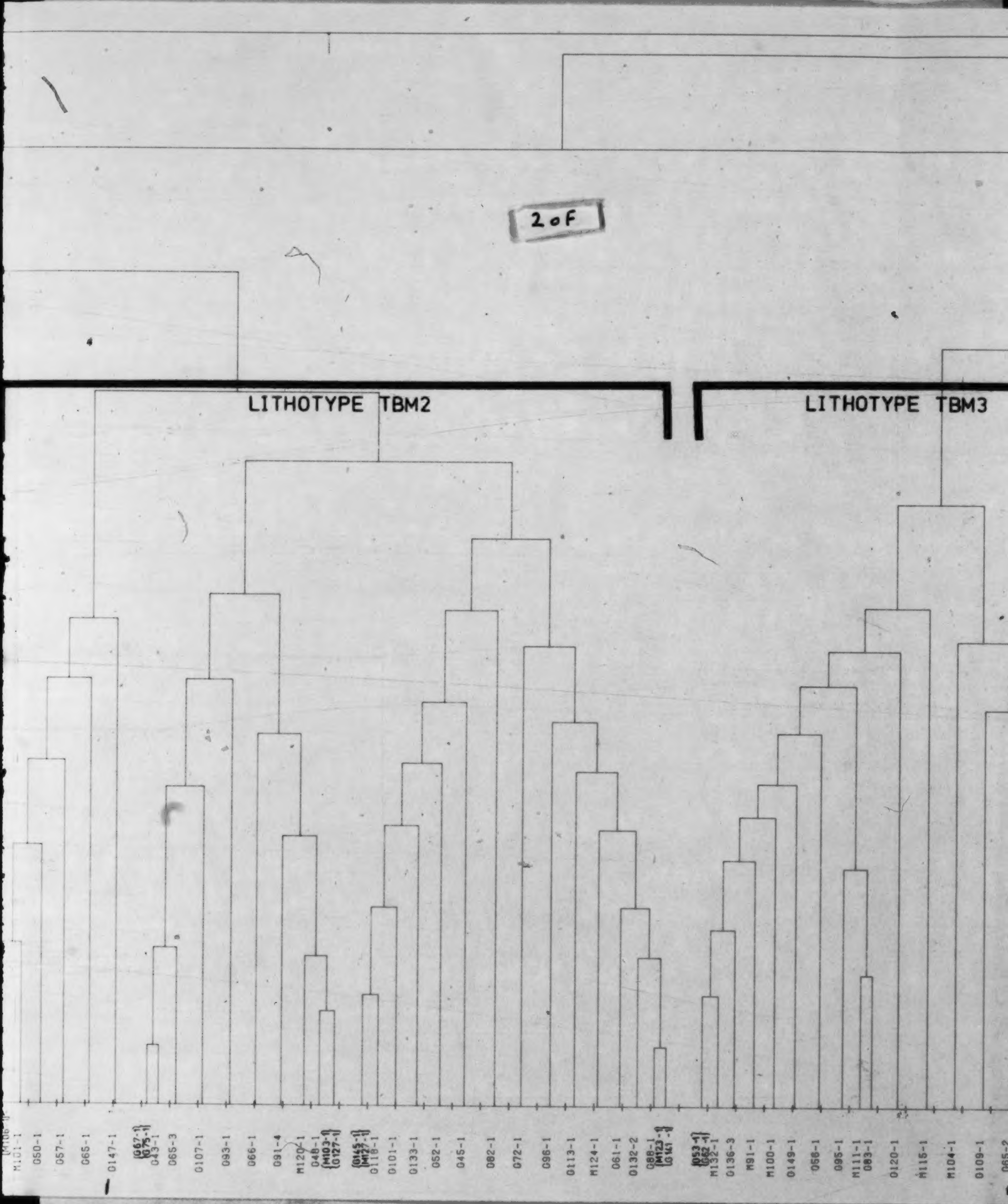
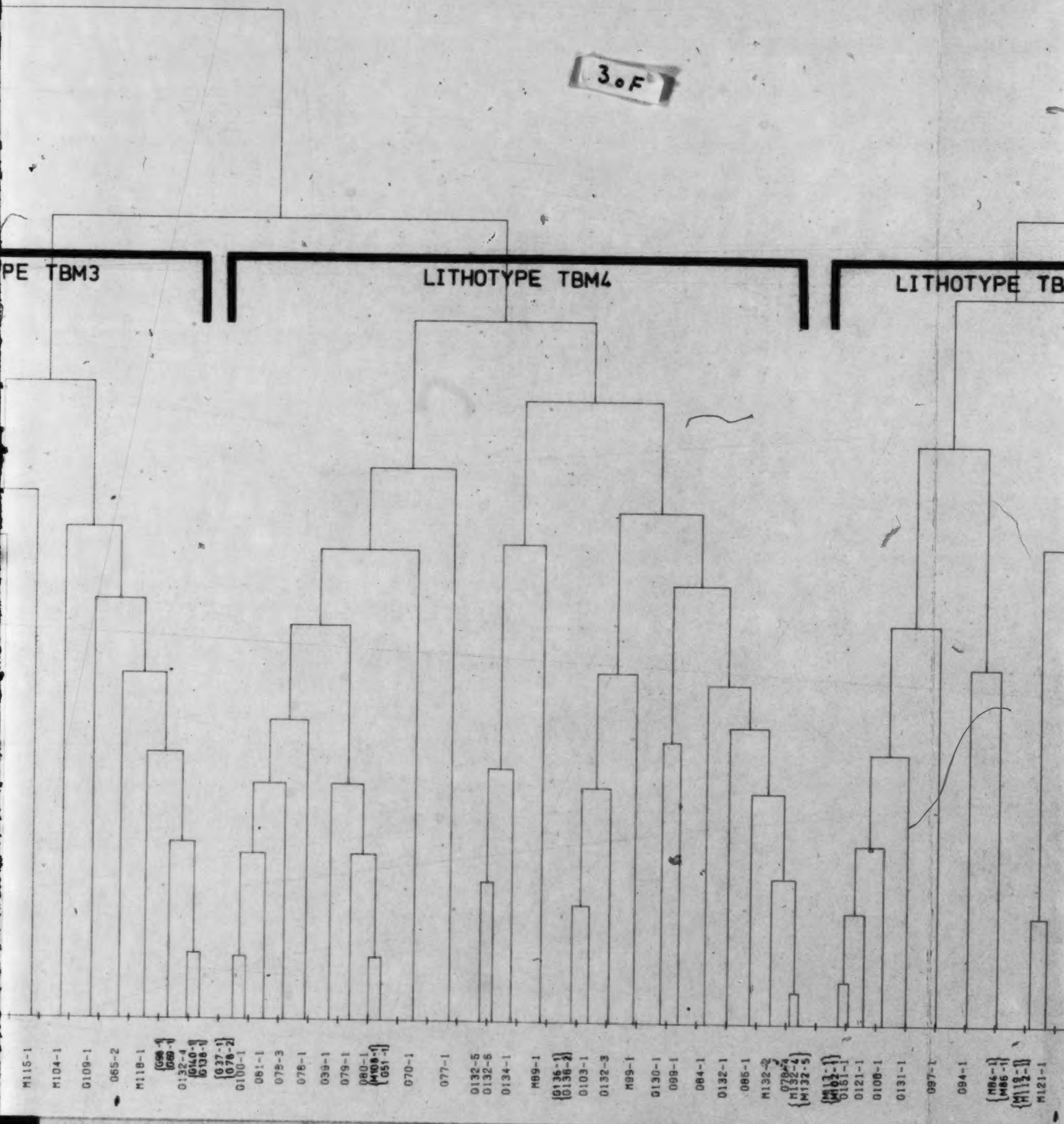

LITHOTYPE TBM2
LITHOTYPE TBM3
(M106-1)
M101-1
G50-1
G57-1
G65-1
G147-1
(G67-1)
(G75-1)
G43-1
G65-3
G107-1
G93-1
G66-1
G91-4
M120-1
G48-1
(M103-1)
(G127-1)
(G145-1)
(M127-1)
G118-1
G101-1
G133-1
G52-1
G45-1
G82-1
G72-1
G96-1
G113-1
M124-1
G61-1
G132-2
G88-1
(M123-1)
(G141-1)
(G53-1)
(G62-1)
M132-1
G136-3
M91-1
M100-1
G149-1
G56-1
G95-1
M111-1
G83-1
G120-1
M115-1
M104-1
G109-1

3oF


PE TBM3
LITHOTYPE TBM4
LITHOTYPE TB
M115-1
M104-1
0109-1
065-2
M118-1
G98-1
G60-1
0132-4
G140-1
G138-1
G37-1
076-2
0100-1
061-1
079-3
078-1
039-1
079-1
080-1
M100-1
G51-1
G70-1
077-1
0132-5
0132-6
0134-1
M89-1
G136-1
G136-2
0103-1
0132-3
M99-1
0130-1
099-1
084-1
0132-1
085-1
M132-2
078-4
M132-4
M132-5
M113-1
M102-1
0151-1
0121-1
0108-1
0131-1
097-1
094-1
M84-1
M86-1
M119-1
M112-1
M121-1

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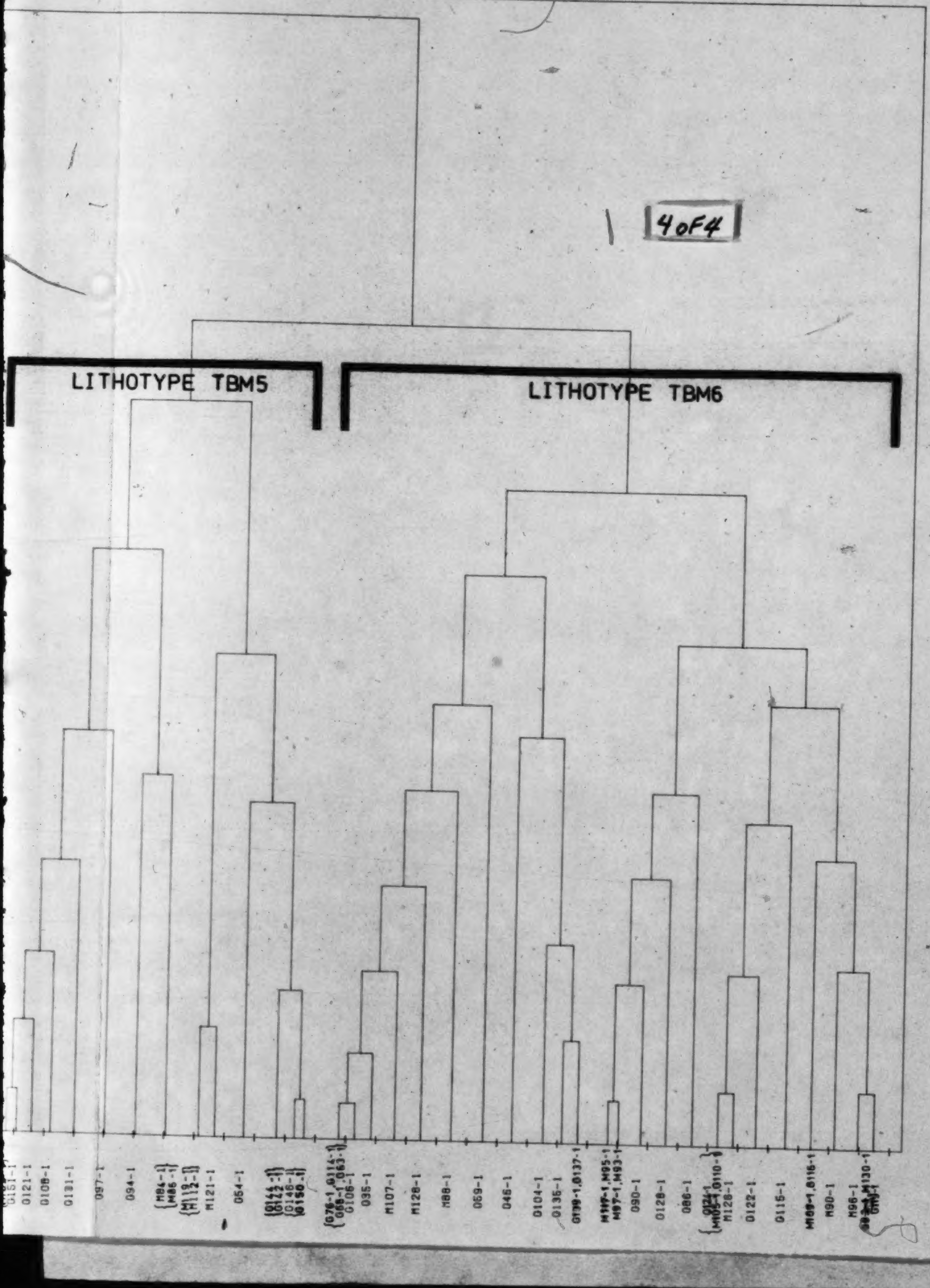
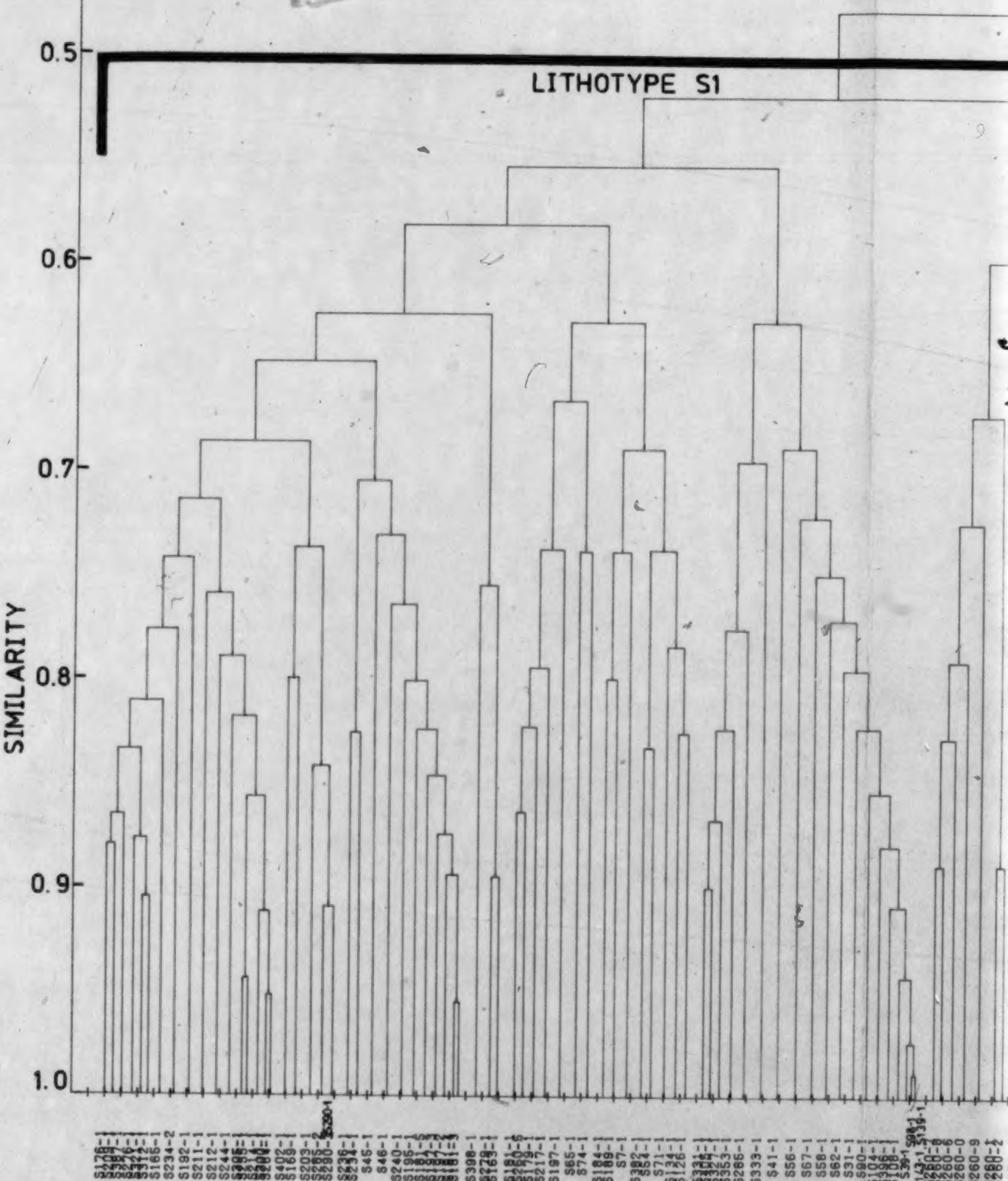
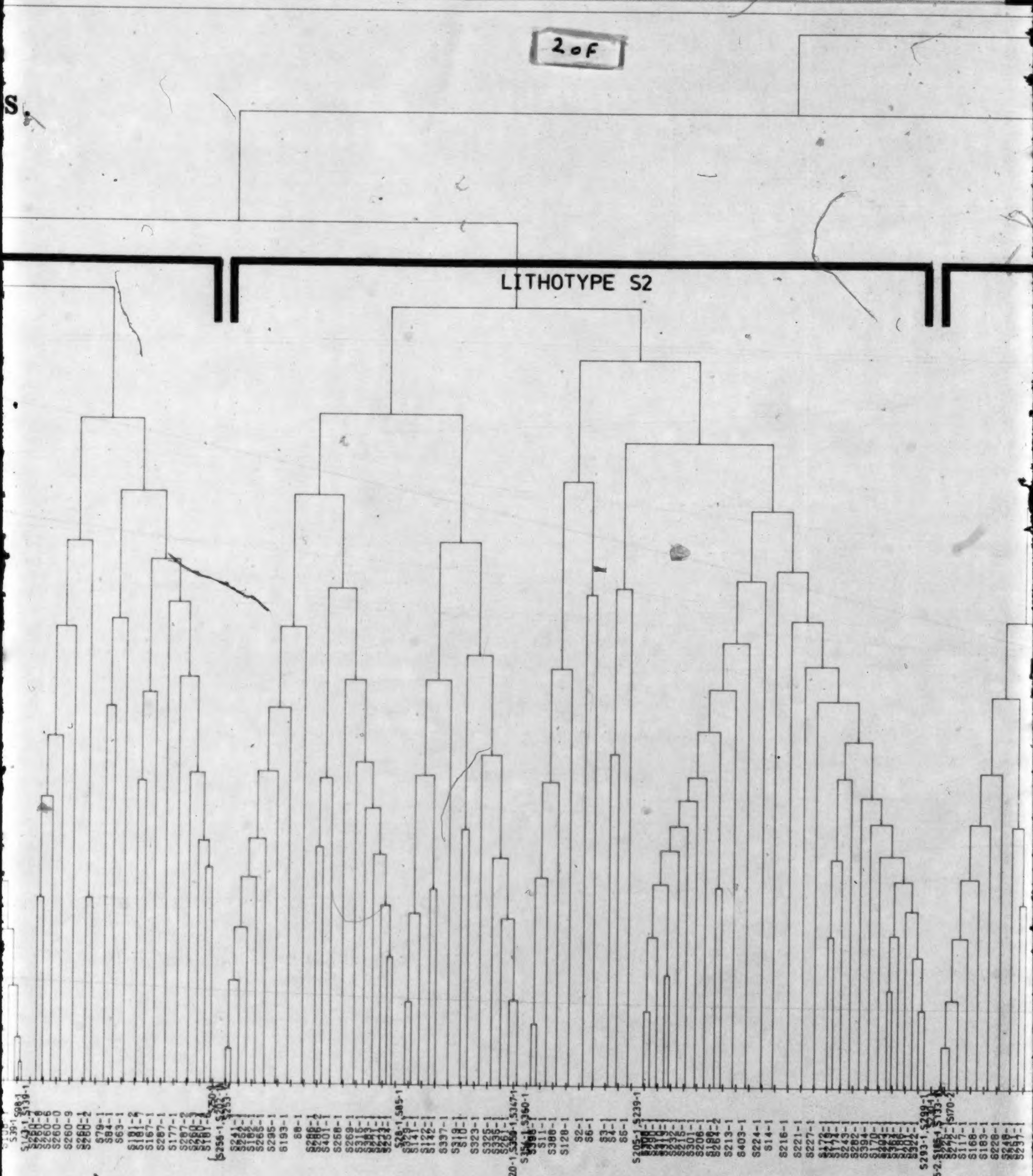

LITHOTYPE TBM5
LITHOTYPE TBM6
0151-1
0121-1
0108-1
0131-1
097-1
094-1
M84-1
M86-1
M119-1
M112-1
M121-1
054-1
0144-1
0142-1
0146-1
0150-1
076-1,0114-1
068-1,063-1
0106-1
095-1
M107-1
M128-1
M88-1
069-1
046-1
0104-1
0136-1
0139-1,0137-1
M119-1,M95-1
M97-1,M93-1
090-1
0128-1
086-1
0124-1
M105-1,0110-1
M126-1
0122-1
0115-1
M109-1,0116-1
M90-1
M96-1
M130-1

Figure 4-9. Dendrograph of Sheep River section samples.

1 of



2 of


S.
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S39-1
S143-1,S130-1
S260-0
S260-9
S260-1
S260-2
S79-1
S84-1
S63-1
S181-2
S167-1
S287-1
S177-1
S287-2
S255-1,S202-1
S241-1
S265-1
S295-1
S193-1
S8-1
S286-1
S401-1
S258-1
S269-1
S315-1
S28-1,S05-1
S141-1
S122-1
S142-1
S337-1
S319-1
S10-1
S323-1
S325-1
S335-1
S320-1,S350-1,S347-1
S354-1,S360-1
S11-1
S380-1
S120-1
S2-1
S6-1
S3-1
S4-1
S5-1
S205-1,S239-1
S215-1
S301-1
S206-1
S213-1
S403-1
S224-1
S14-1
S216-1
S221-1
S227-1
S243-1
S282-1
S394-1
S170-1
S293-1,S290-1
S245-2,S185-1,S133-1
S170-2
S117-1
S168-1
S183-1
S228-1
S248-1
S237-1

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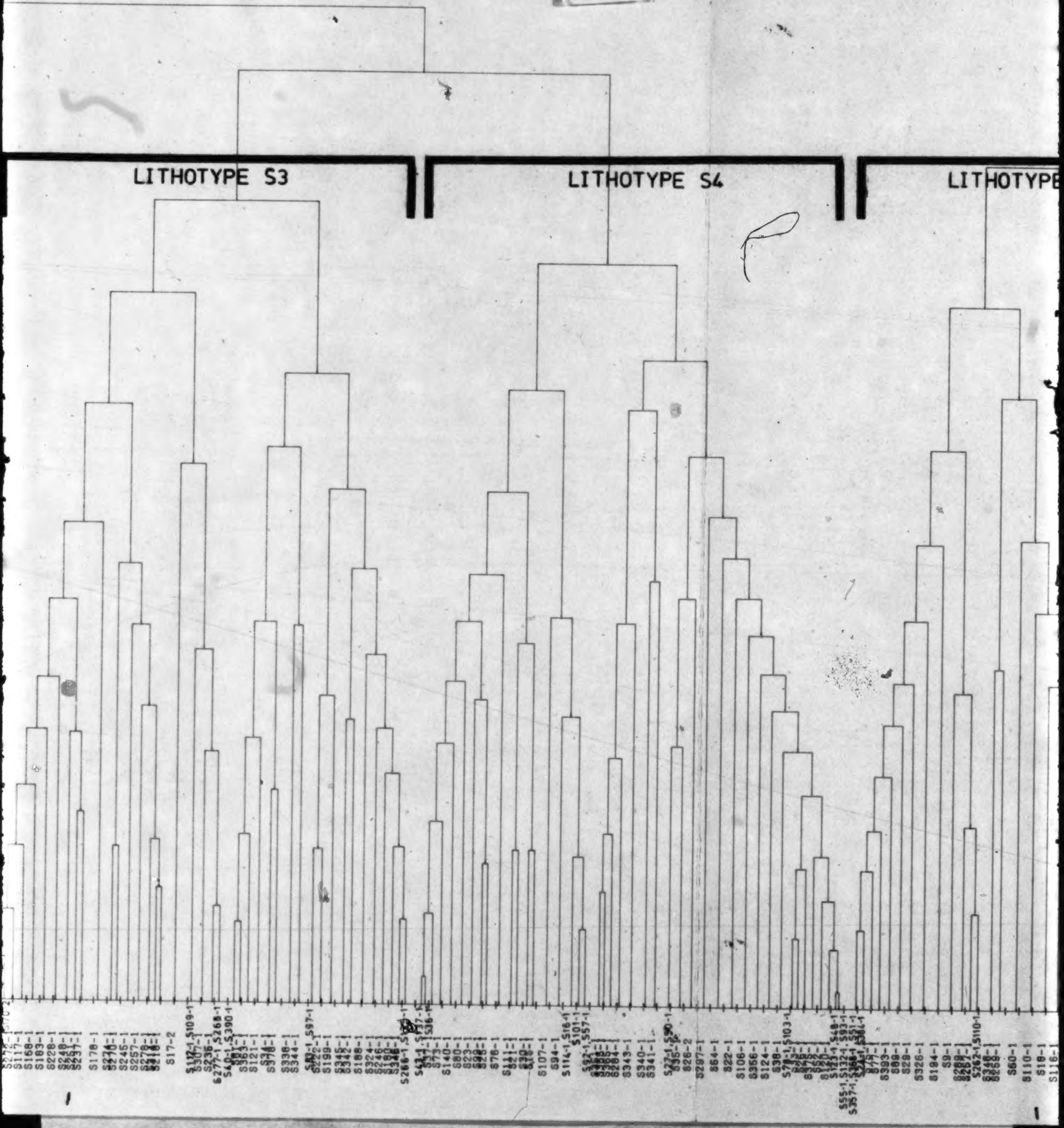
LITHOTYPE S3
LITHOTYPE S4
LITHOTYPE
S117-1
S168-1
S183-1
S228-1
S178-1
S245-1
S257-1
S17-2
S109-1
S307-1
S236-1
S277-1
S268-1
S40-1
S390-1
S121-1
S336-1
S344-1
S97-1
S222-1
S199-1
S342-1
S188-1
S324-1
S246-1
S266-1
S43-1
S37-1
S36-1
S73-1
S140-1
S80-1
S23-1
S78-1
S21-1
S107-1
S94-1
S114-1
S16-1
S101-1
S57-1
S343-1
S340-1
S341-1
S27-1
S95-1
S26-2
S297-1
S64-1
S22-1
S106-1
S356-1
S124-1
S38-1
S103-1
S48-1
S93-1
S51-1
S55-1
S132-1
S357-1
S77-1
S393-1
S89-1
S29-1
S326-1
S184-1
S9-1
S262-1
S110-1
S60-1
S110-1
S19-1
S116-1

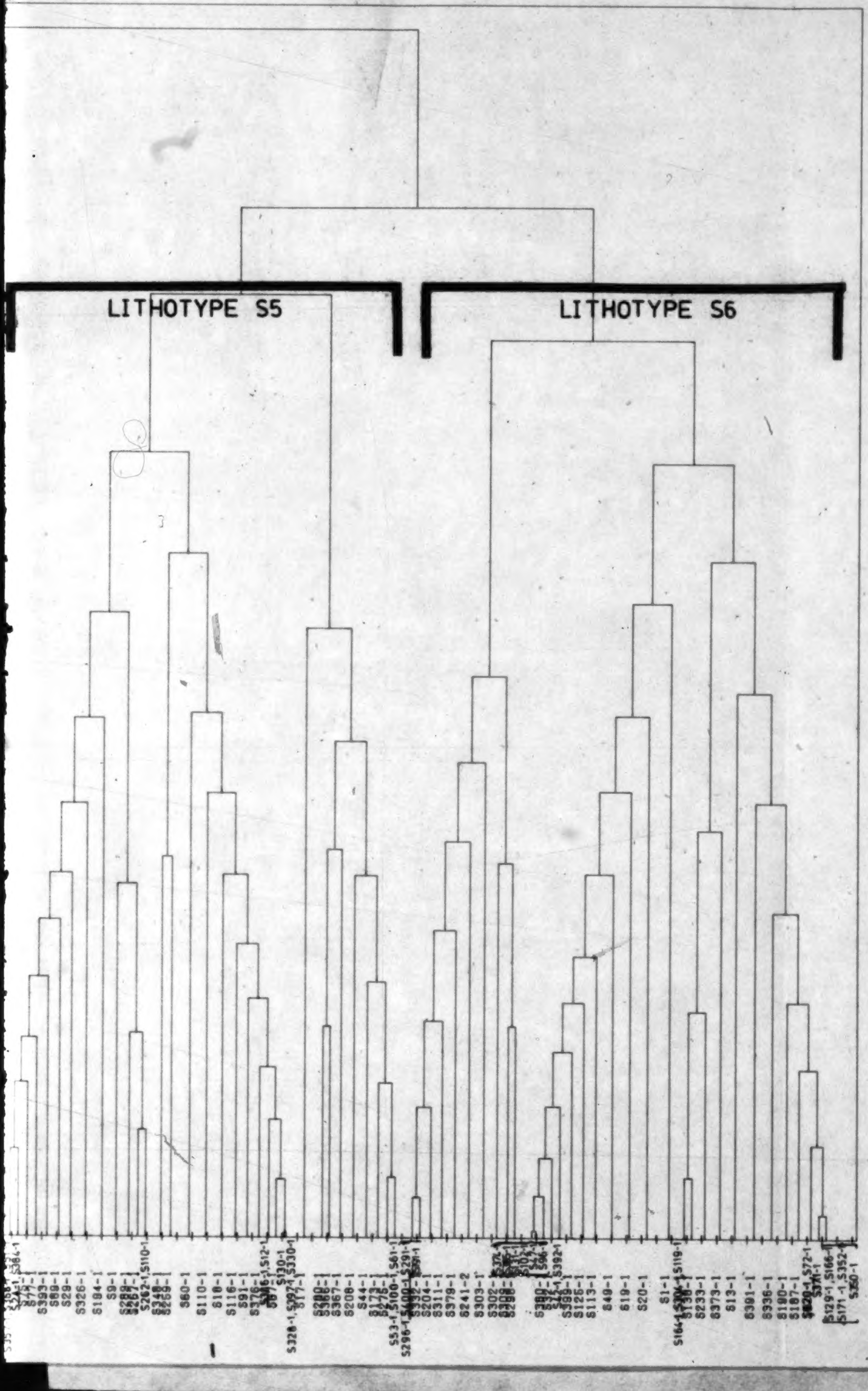
LITHOTYPE S5
LITHOTYPE S6
S324-1,S384-1
S77-1
S393-1
S89-1
S29-1
S326-1
S184-1
S9-1
S289-1
S267-1
S262-1,S110-1
S348-1
S259-1
S60-1
S110-1
S10-1
S116-1
S91-1
S376-1
S96-1,S12-1
S97-1
S130-1
S328-1,S397-1,S330-1
S77-1
S200-1
S366-1
S367-1
S208-1
S44-1
S173-1
S275-1
S53-1,S100-1,S61-1
S296-1,S400-1,S291-1
S392-1
S204-1
S311-1
S379-1
S241-2
S303-1
S302-1
S309-1
S298-1
S380-1
S392-1
S399-1
S126-1
S113-1
S49-1
S19-1
S20-1
S1-1
S164-1,S304-1,S119-1
S130-1
S233-1
S373-1
S13-1
S391-1
S336-1
S190-1
S187-1
S320-1,S72-1
S371-1
S129-1,S166-1
S171-1,S352-1
S350-1

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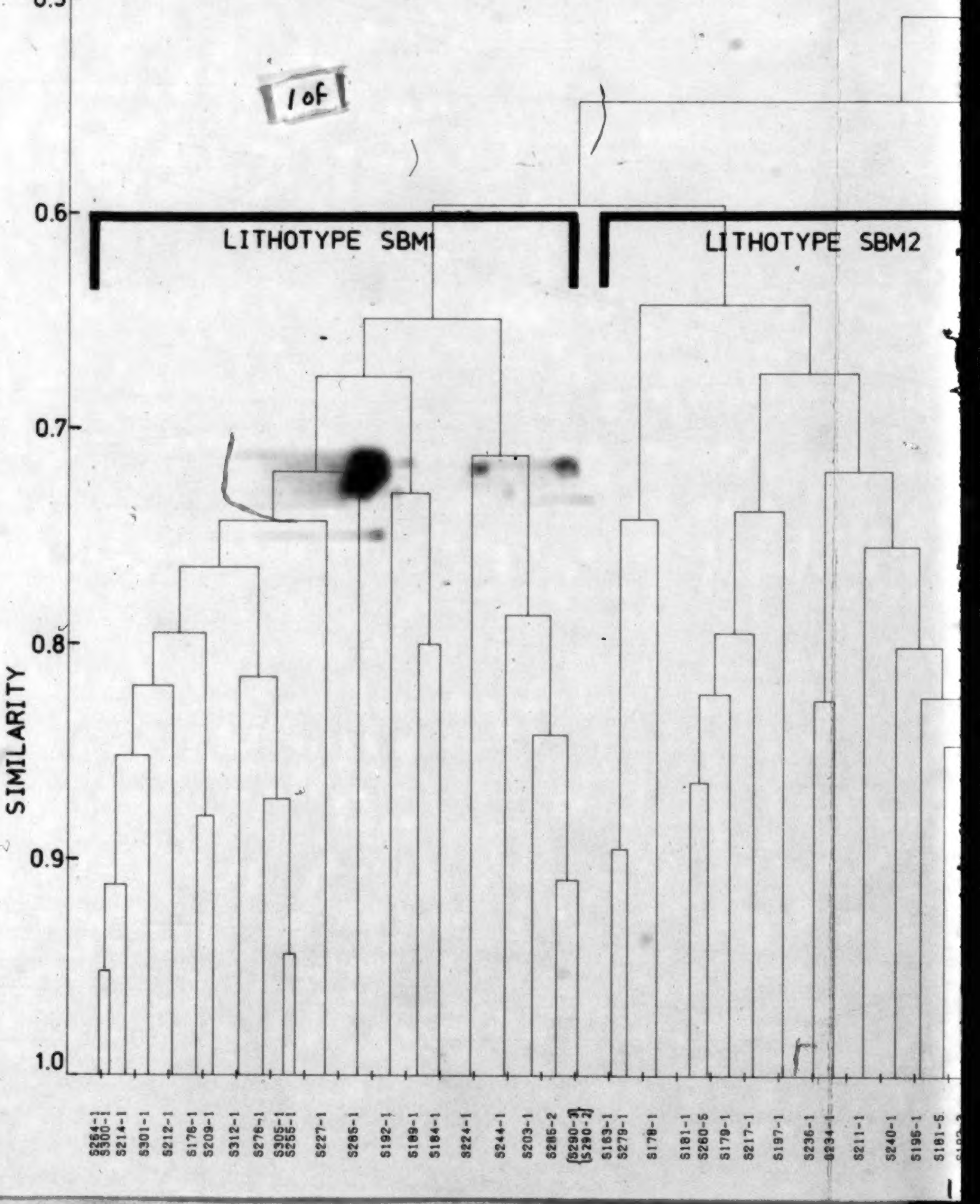
Figure 4-10. Dendrograph of Sheep River section Beaver Mines F'm. samples.

1of



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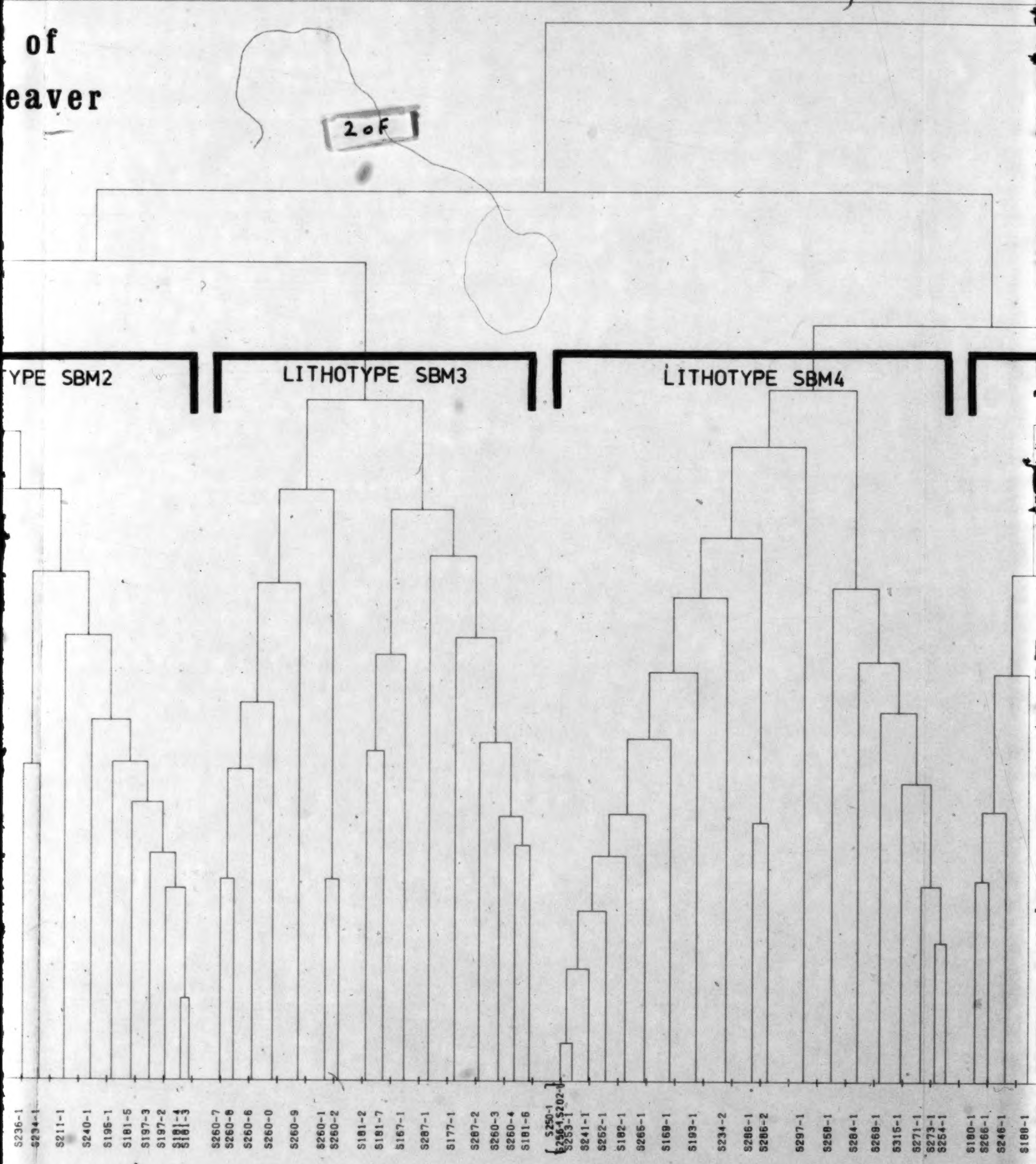
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LITHOTYPE SBM3
LITHOTYPE SBM4
S236-1
S234-1
S211-1
S240-1
S195-1
S181-5
S197-3
S197-2
S181-4
S181-3
S260-7
S260-8
S260-6
S260-0
S260-9
S260-1
S260-2
S181-2
S181-7
S167-1
S287-1
S177-1
S287-2
S260-3
S260-4
S181-6
S250-1
S256-1,S202-0
S253-1
S241-1
S252-1
S182-1
S265-1
S169-1
S193-1
S234-2
S286-1
S286-2
S297-1
S258-1
S284-1
S269-1
S315-1
S271-1
S273-1
S254-1
S180-1
S266-1
S246-1
S188-1

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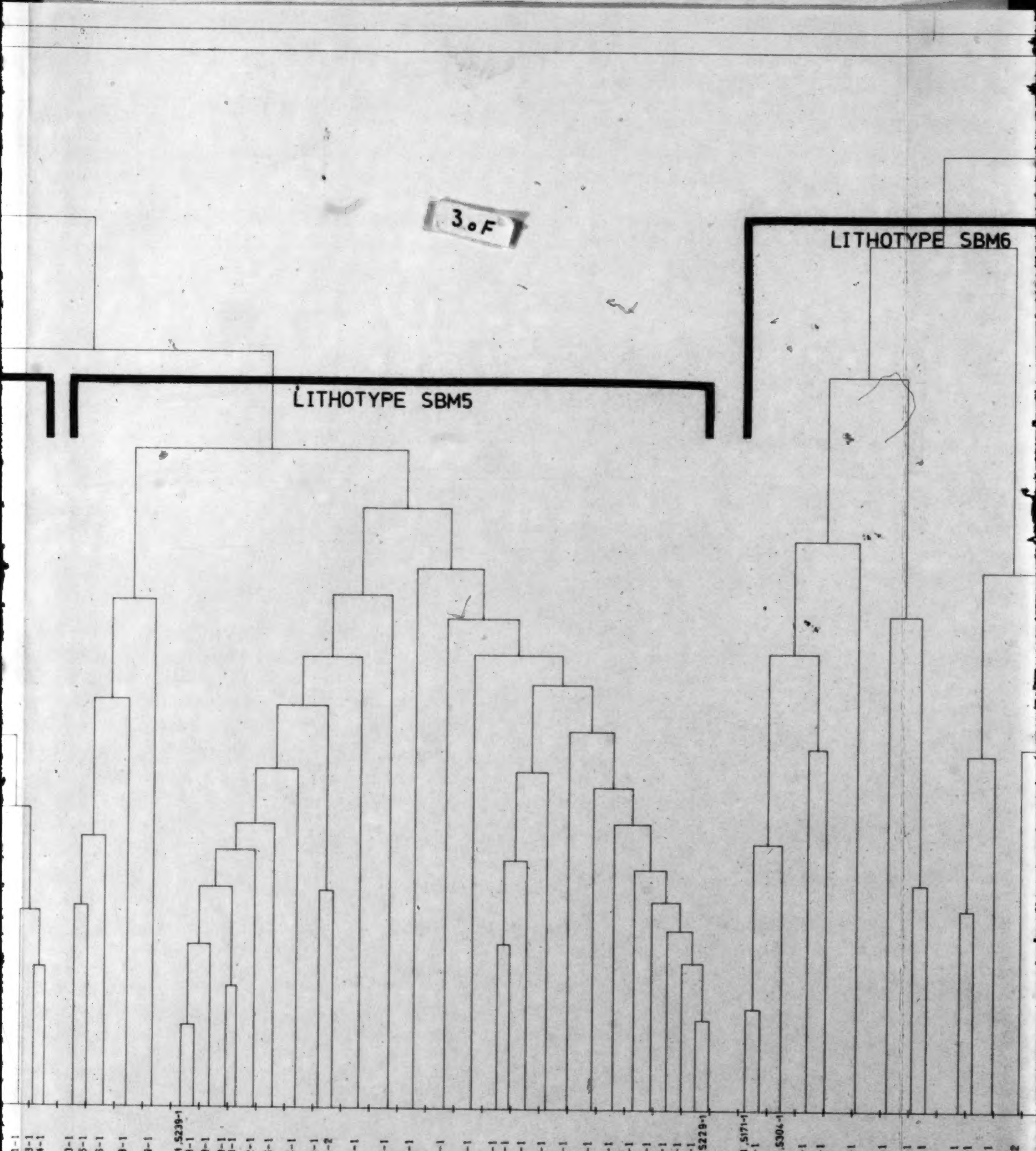

LITHOTYPE SBM5
LITHOTYPE SBM6
S271-1
S273-1
S254-1
S180-1
S266-1
S246-1
S188-1
S199-1
S205-1,S239-1
S308-1
S280-1
S310-1
S313-1
S232-1
S215-1
S295-1
S198-1
S264-2
S213-1
S259-1
S216-1
S221-1
S222-1
S172-1
S219-1
S174-1
S243-1
S165-1
S261-1
S282-1
S170-1
S186-1
S201-1
S223-1
S207-1
S299-1,S229-1
S166-1,S171-1
S220-1
S164-1,S304-1
S187-1
S190-1
S208-1
S280-1
S276-1
S173-1
S290-1
S309-1
S302-1
S241-2

4oF4

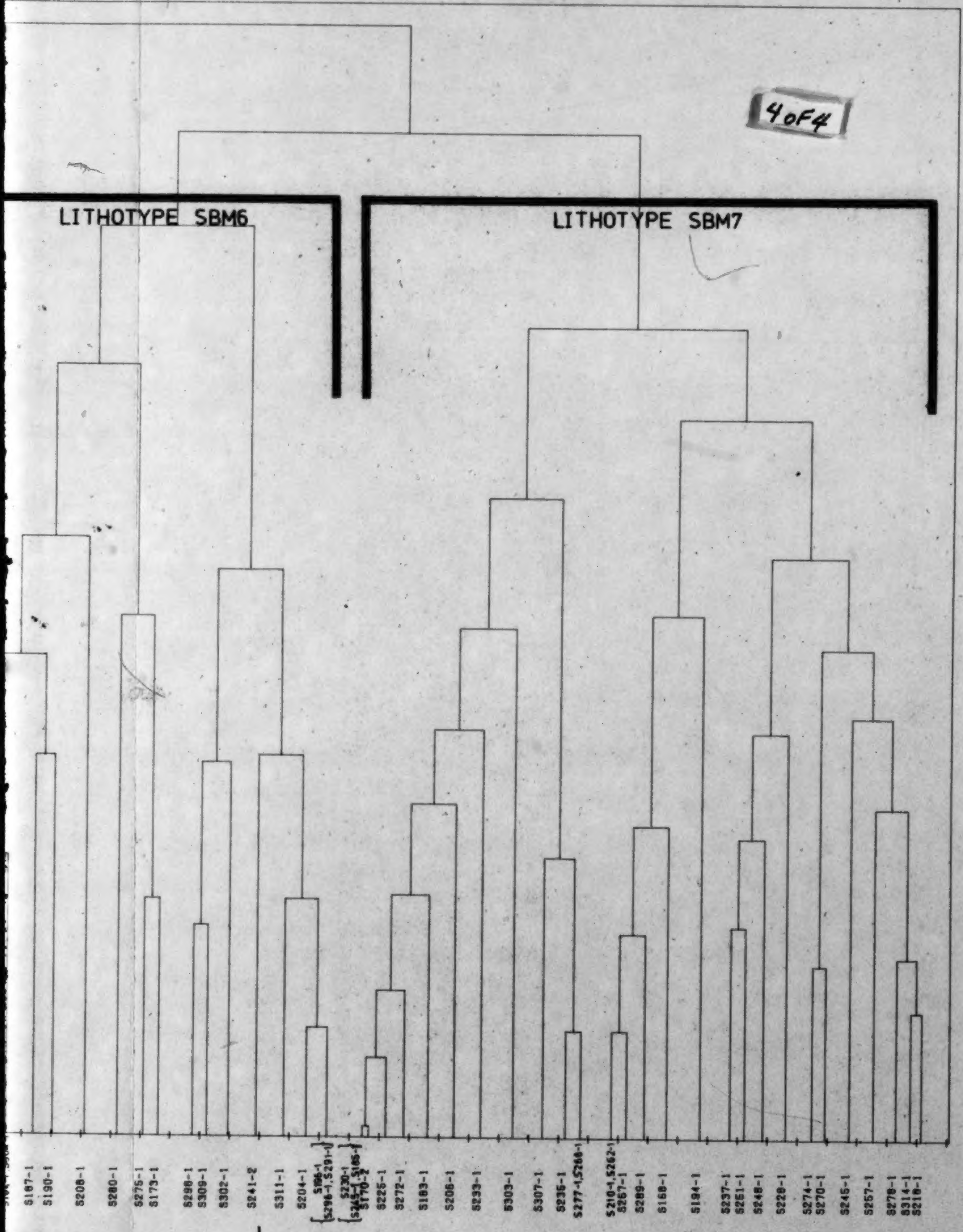
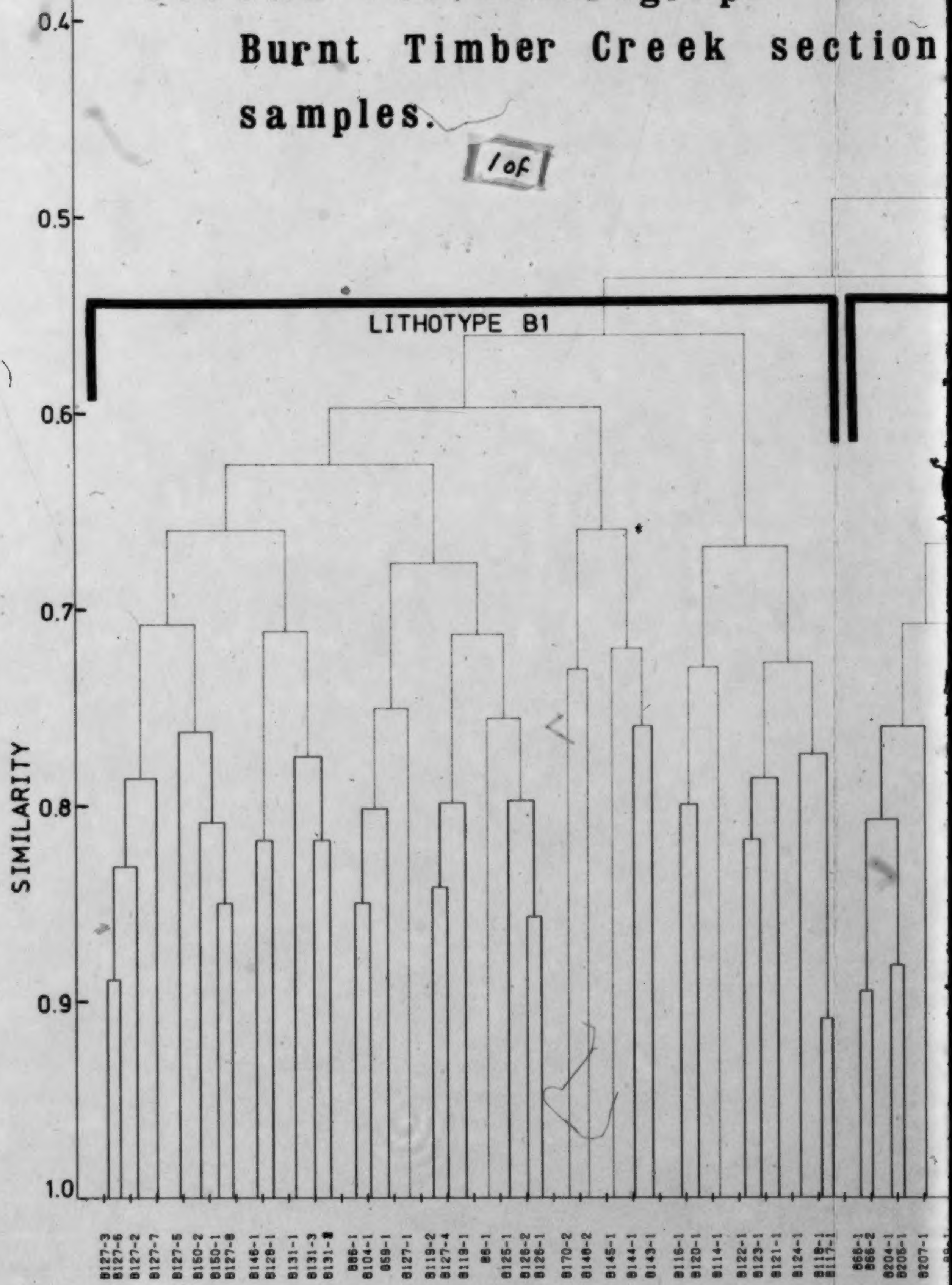

LITHOTYPE SBM6
LITHOTYPE SBM7
S187-1
S190-1
S208-1
S280-1
S275-1
S173-1
S298-1
S309-1
S302-1
S241-2
S311-1
S204-1
S186-1
S296-1, S291-1
S230-1
S245-1, S165-1
S170-2
S225-1
S272-1
S183-1
S206-1
S233-1
S303-1
S307-1
S235-1
S277-1, S268-1
S210-1, S262-1
S267-1
S289-1
S168-1
S194-1
S237-1
S251-1
S248-1
S228-1
S274-1
S270-1
S245-1
S257-1
S278-1
S314-1
S218-1

FIGURE 4-13. Dendrograph of
Burnt Timber Creek section
samples.

1of



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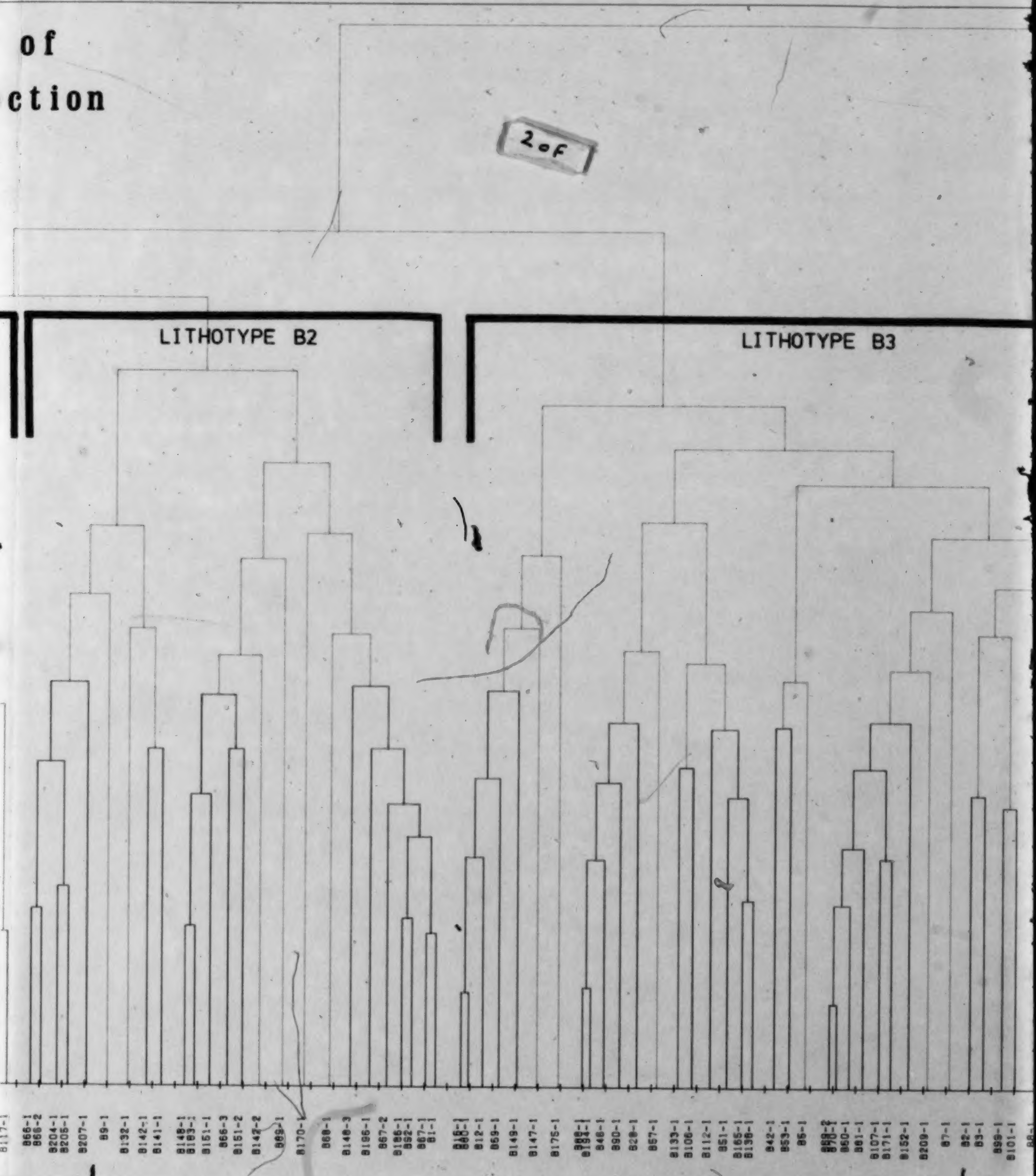
2 of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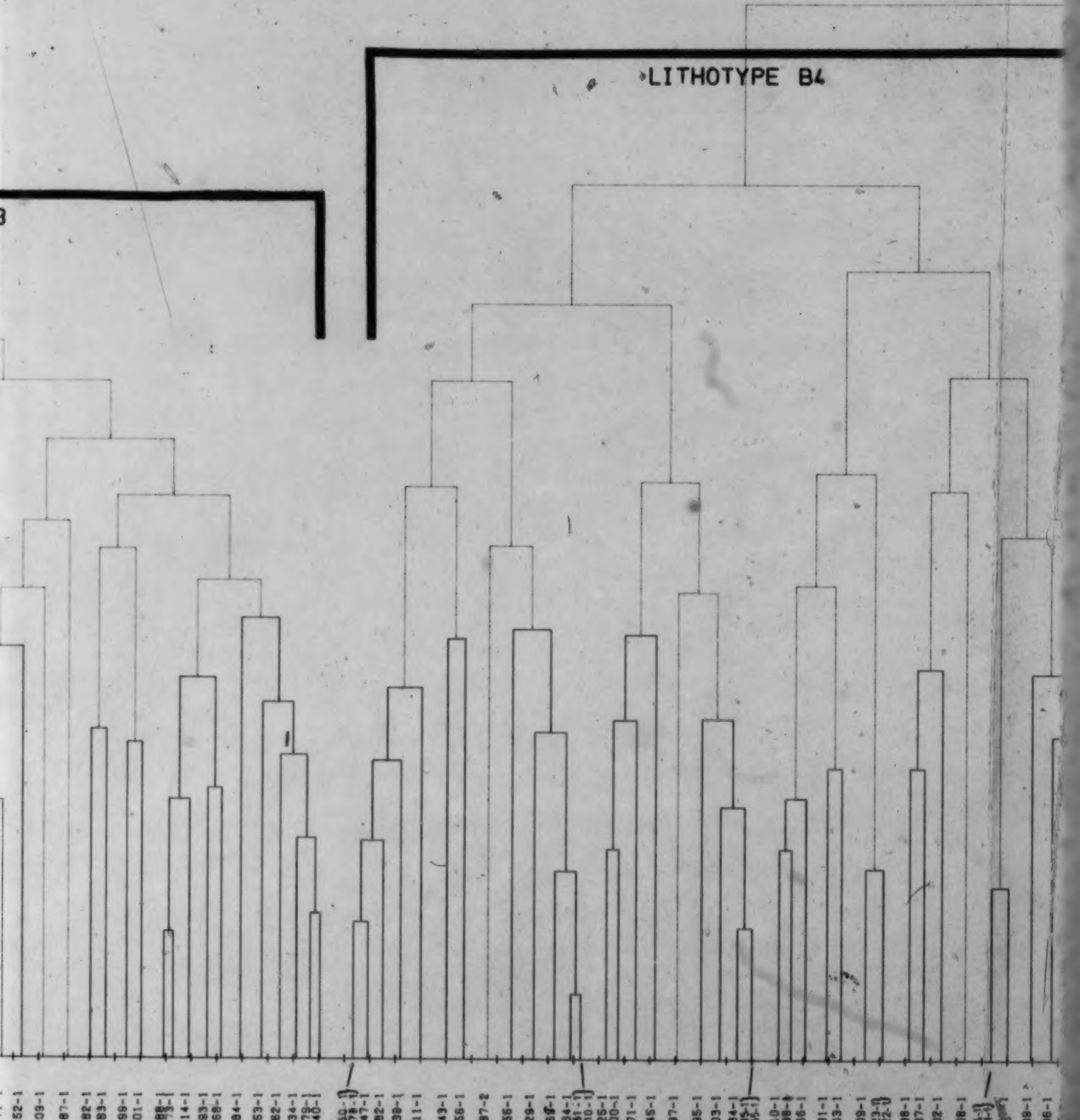
B117-1
B66-1
B66-2
B204-1
B205-1
B207-1
B9-1
B132-1
B142-1
B141-1
B148-1
B183-1
B151-1
B66-3
B151-2
B142-2
B89-1
B170-1
B68-1
B148-3
B196-1
B67-2
B186-1
B92-1
B67-1
B1-1
B16-1
B80-1
B12-1
B69-1
B149-1
B147-1
B175-1
B88-1
B194-1
B46-1
B90-1
B28-1
B57-1
B133-1
B106-1
B112-1
B51-1
B165-1
B138-1
B42-1
B53-1
B5-1
B69-2
B70-1
B60-1
B61-1
B107-1
B171-1
B152-1
B209-1
B7-1
B2-1
B3-1
B99-1
B101-1
B8-1

3oF


B
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B2-1
B3-1
B99-1
B101-1
B8-1
B73-1
B14-1
B83-1
B168-1
B4-1
B153-1
B62-1
B34-1
B79-1
B40-1
B160-1
B178-1
B47-1
B82-1
B139-1
B11-1
B43-1
B156-1
B7-2
B55-1
B129-1
B169-1
B134-1
B61-1
B10-1
B25-1
B200-1
B71-1
B45-1
B97-1
B95-1
B103-1
B184-1
B195-1
B65-1
B110-1
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B163-1
B109-1
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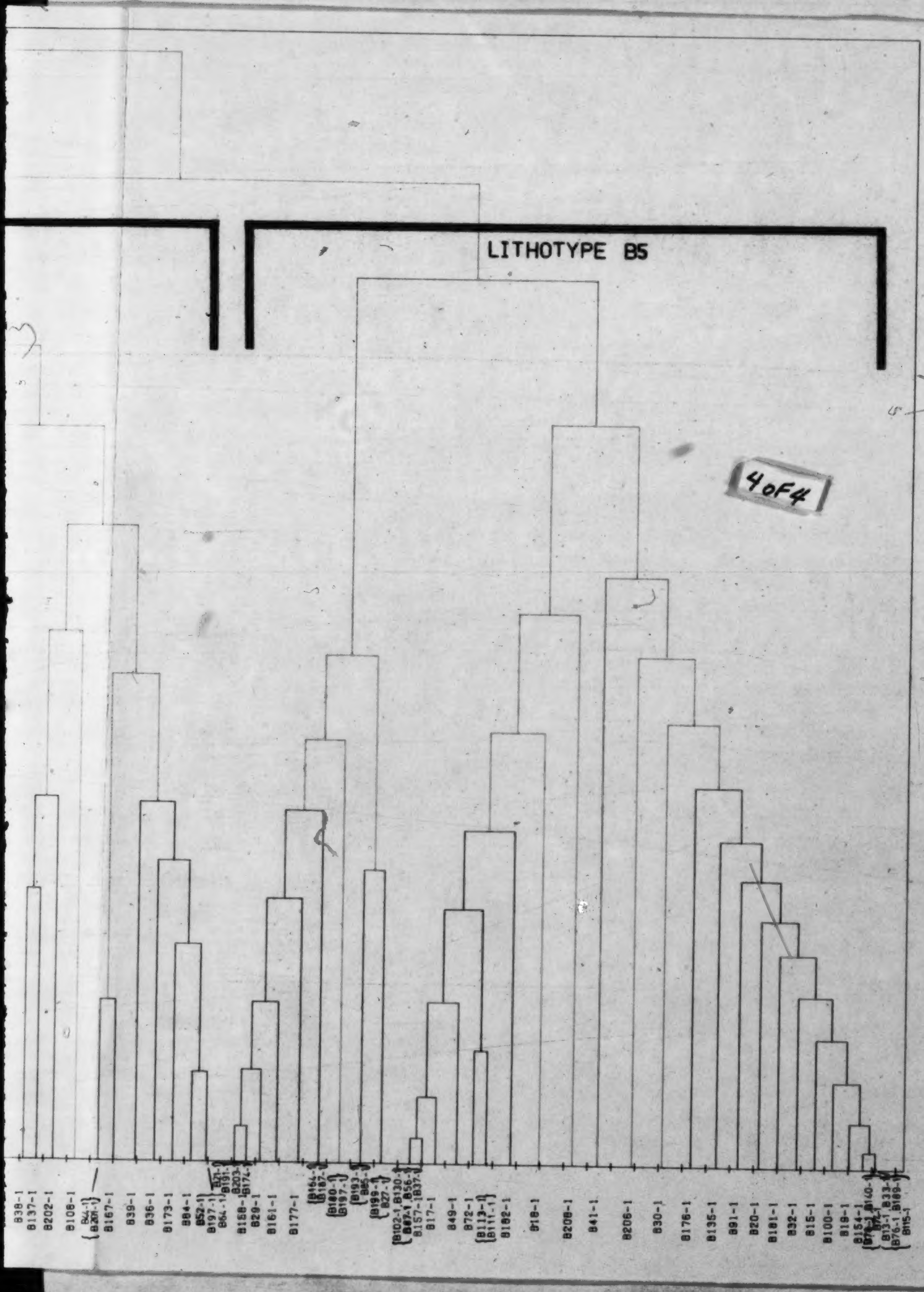
B26-1
B39-1
B36-1


LITHOTYPE B5
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B137-1
B202-1
B108-1
B44-1
B204-1
B167-1
B39-1
B36-1
B173-1
B84-1
B52-1
B197-1
B64-1
B21-1
B191-1
B158-1
B203-1
B174-1
B29-1
B161-1
B177-1
B164-1
B187-1
B180-1
B197-1
B193-1
B85-1
B199-1
B27-1
B102-1, B130-1
B87-1, B56-1
B157-1, B37-1
B17-1
B49-1
B72-1
B113-1
B111-1
B182-1
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B208-1
B41-1
B206-1
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B100-1
B19-1
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B115-1